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DESIGN AND DEVELOPMENT
OF AN
AUTOMATIC REFRIGERATOR CAR HEATER

A Case History

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FOREWORD

This case history has two objectives:

1. *To tell how a design was developed.*

2. *To serve as background for design problems for practice by students.*

Several problems are suggested at the end of Section I and at the end of Section V. Others will suggest themselves to instructors.

The story is quite typical in some respects, unusual in others.

It is typical in the difficulties which engineers had in learning the true requirements, the actual conditions of service, and the behavior of different materials in the field. The problem was also typical in involving several different fields of knowledge and phenomena which were not found in books or known to the expert consultants. Solutions were found by the iterations which are typical of design and which look like fumbling to outsiders.

The story is unusual in telling about a design not as it was planned, nor as hindsight shows it should have been done, but as it actually happened. *For this we owe sincere gratitude to the managements and the people of Preco Incorporated and of the Pacific Fruit Express Company, especially Mr. K.V. Plummer and Mr. P.K. Beemer, who so generously gave their time and so candidly told the story.*

Many friends in the Department of Engineering of the University of California, Los Angeles, and in the National Commission for Engineering Education deserve thanks for their encouragement and suggestions; so does the Educational Development Program at UCLA which made funds donated by the Ford Foundation available for this project.

H.O. Fuchs
February 1963

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I. BACKGROUND

The transportation of perishable commodities over long distances is an essential part of our daily life. Bostonians eat fresh California lettuce, and Texans bake Idaho potatoes. Much of this transportation depends on the 100,000 refrigerator cars operated by American railroads.[1] These insulated box cars are cooled in summer and heated in winter under a variety of "protective services" available to shippers.[2] Heater service is one of these. It had been performed for about 50 years by means of charcoal heaters. They are approximately 15 inches in diameter and 30 inches high and can be installed in the ice bunkers located at each end of the refrigerator car, accessible through hatches in the car roof.

After the end of World War II, Pacific Fruit Express Company, one of the largest refrigerator car lines, suggested to Preco that it should develop a thermostatically controlled liquid fuel heater. Preco Incorporated (originally Pacific Railway Equipment Company) was founded in 1937 by William Van Dorn, an inventor, and Cortland Hill, a young capitalist, to develop and exploit the invention of the pendulum type passenger car for vastly increased riding comfort on railways.[3] Three such cars had been built and sold at a substantial loss in money and an immense gain in established reputation, when World War II intervened. Preco had also developed a profitable business in patented air-circulating fans for railway refrigerator cars. By 1946 this business amounted to several million dollars per year; the Preco staff consisted of about 100 people. Seventeen worked in the product engineering department, seven of these were graduate engineers.* Other engineers worked in the manufacturing department. Based on policies of quality products, good service and attentive selling, the company enjoyed an excellent reputation with its customers. Organization charts of the Preco engineering department for the years 1946, 1952, and 1960 are shown in Appendix A.

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*Three from Stanford, one each from California Institute of Technology, University of South California, Rose Polytechnic, and a German university.

In spring, 1946, Preco management asked their engineers to take a PFE heater (shown in Patent 2,433,829, Appendix D), add a thermostatic control device, and redesign it for quantity production. It was believed that this would be a straightforward job without complications. Pilot models of the heater should be ready for competitive trials conducted by the American Association of Railroads and the U. S. Department of Agriculture in the winter, 1946-1947.[4]

Two modifications of the PFE sample heater were built to gain experience quickly: one of galvanized steel, the other of stainless (Models EA1 and EA2). Both had tubular wicks and a snuffer controlled by hand. At the same time, designs and preliminary tests on the thermostat were started. Model GB1, with solid wick and thermostat, was entered in the competitive tests of 1946-47. By 1949, about 5,000 heaters had been sold. These were designed for and made by high-production tools (for about 10,000) which Preco management had decided to order in the expectation that a good, finished looking product could defeat all competition and later be sold in large quantities.

By 1952 the railroad heater was solidly established. By 1962 Preco had sold about 80,000 heaters of the same basic design for a total of about \$6 million. Initial engineering costs for the railroad heater were about \$100,000. Full time of one graduate engineer was devoted to this product for the first ten years; the entire engineering and sales departments were deployed in heater modifications during an emergency in 1949.

Preco had filed a patent application in November 1949. The patent office found that several separate inventions were involved and issued three patents in 1955 and 1956:

2,717,590	Thermostatically Controlled Wick Type Heater - September 13, 1955
2,741,904	Flame Snuffer for Wick Burner
2,742,318	Thermostatic Control Unit

This last patent, and one page of the first patent, are shown in Appendix D. Preco also designed and sold heaters in which the basic design was modified. One of these is intended for service in trucks and trailers. Trucks and trailers overturn much more often than railroad cars and do not have separate bunkers in which the heaters can be installed. The modifications prevent contact of the load with the hot chimney, shut off fuel flow to the wick, and close the tank vent when the heater is tipped too far off the vertical, and extinguish the flame in case of accident. Another modification increases the output of the heater from about 6,000 BTU/hour to twice that value.

A third modification is intended for service in insulated box cars without end bunkers. Some commodities which must be protected from freezing, such as beer, cosmetics, and pharmaceuticals, are shipped in solid loads in such cars. The heaters are suspended from the car ceiling in a manner which prevents excessive swaying and damage from shocks when trains are made up in switch-yards.

II. DEVELOPMENT AND USE OF AUTOMATIC HEATERS

by Kenneth V. Plummer
formerly Vice President and General Manager
Pacific Fruit Express Company

I have endeavored to provide a brief summary of the development and use of the thermostatically controlled alcohol heater in the field of transportation. Let me say at the start, however, that without the help of Assistant Traffic Manager Peters and Assistant General Manager Holst of the PFE Company I would have been hard put to come up with authentic information on the subject.

Prior to the "Roaring Twenties" and even up to the late "forties" railroads in the United States used charcoal heaters to protect perishable commodities from freezing while in transit during severe weather conditions. Generally these heaters were placed in the bunkers of refrigerator cars and lighted or extinguished on the basis of outside temperatures prevailing along the route of travel. As a rule more heat was generated than actually required but the general run of commodities handled seemed to withstand this treatment and for many years the industry viewed the service in a reasonably satisfactory light.

As new farm lands developed and cold storage plants were built for the purpose of extending marketing potentials over a longer period, shippers of fresh fruits began to take a dim view of the overheating of their products while in transit and appealed to the carriers to do something about it.

In 1930 a small but determined group of shippers in the Pacific Northwest rebelled and a few threatened to divert traffic over southern routes or to the waterways unless something was done to improve transit temperatures. Some of them discontinued using heater service and instead used straw or sawdust on the floors at times soaking these materials with water on the theory the freezing of the water would give off some heat and protect the commodity in the car. Others tried sending their own employees with the shipment to manipulate the heaters en route*. None of these ideas produced the desired results and were eventually discarded.*

The carriers were as much interested in the problem as were the shippers and appointed a general committee to work with them in finding a solution. Manufacturers of heaters were also brought into the picture and the U.S. Department of Agriculture lent their assistance in setting up a coordinated program of research and development.

Some test runs were made under which heaters were lighted and extinguished on the basis of inside car temperatures prevailing at each inspection point, but because of the elapsed time between stations and the vagaries of the weather encountered en route, the end result was no better than prevailed under the standard method of manipulating heaters on the basis of outside temperatures which incidentally could be handled more expeditiously and with less expense.

Then followed changes in the design of heaters. New type dampers were installed on charcoal heaters, some with automatic controls. Manually operated alcohol heaters were brought into general use. A few tests were made with underslung heaters which circulated heat in pipes laid on top of the car floor. A butane heater was given a trial but proved too fragile for railroad service. Another type heater had a rotor fan for distributing the warm air throughout the lading. Some slight improvements became apparent but not sufficient to satisfy the needs of the industry. Overheating persisted and the cost of providing the service was constantly on the rise.

In 1933 Pacific Fruit Express Co., always a leader in the car line field, decided upon a new approach and purchased 20 thermostatically controlled alcohol heaters. Working in conjunction with the other Northwest carriers and the shippers in that area, extensive test work was undertaken to determine the merits of these new units. At the same time the other carriers vigorously pressed their research on charcoal and other types of heaters, but the progress was agonizingly slow. Several mild winters were encountered during which heater service was required to a very limited extent. Laboratory testing was impracticable because of the difficulty in simulating the many variables encountered in road service. There seemed to be no alternative to the exercise of patience and the waiting for weather favorable to test runs - and that policy was necessarily followed in spite of the many delays experienced.

The alcohol heaters soon demonstrated their superiority over the charcoal type but many new problems arose. Denatured alcohol did not work well because of its attraction for moisture, causing rust in the tanks and crusting of the wicks. This type of fuel was later discarded in favor of a combination of two-thirds methanol and one-third isopropanol. Carburetors used on the early models of automatic alcohol heaters gave trouble because of sticking needle valves. Bellows type thermostats worked satisfactorily at sea level but failed at high altitudes where the most severe weather prevailed. Asbestos wicks also proved troublesome and were later replaced with glass fibre wicks. These and a myriad of other problems required painstaking studies

and a world of patience all around. The greatest deterrent to progress was the weather because, as previously stated, the opportunity for running productive road tests existed only a few weeks each year. World War II also had its effect as the carriers had neither the man power nor equipment that could be held aside awaiting favorable weather for testing purposes.

Following World War II car lines and railroads embarked upon a huge car building program to replace old and worn out equipment. In these new cars many improvements were incorporated such as added insulation, air circulating fans and side wall flues. Here again less heat was required to protect shipments against freezing and the problem of over heating became more acute. It was obvious that nothing short of automatically controlled heat would do the job.

In 1946 Pacific Railway Equipment Company - commonly known as Preco - entered the field and in collaboration with PFE engineers and others vigorously attacked the problem at hand. This Company, with its aggressive management and sales policies plus an extremely capable group of engineers, had already done an outstanding job in developing air circulating fans for refrigerator cars and was well equipped in every way to take on this new challenge.

Benefiting by the research work already done they were able, in a relatively short time, to come up with a thermostatically controlled heater that held great promise. It was by no means perfect and many improvements had to be made, but fundamentally it was sound and the same basic features are still in use today.

By 1948 Preco had so well demonstrated its superiority over all other types of heaters that PFE placed an order for 1110 of these units - the first large order Preco had received. Over 11,000 of these heaters are now in the service of the Pacific Fruit Express Co. Other car lines and railroads also recognized the superiority of the Preco heater and about the same time started ordering them for service in their respective territories. The transition from the charcoal to the thermostatically controlled heaters was extremely slow in some areas because of the investment involved and the small revenue accruing from heater services. It was also a fact that many of the more hardy products did not require controlled temperatures and the charcoal heater was doing a sufficiently good job for all intents and purposes.

The die was cast, however, for the automatically controlled heater and we now find more than 70,000 Preco heaters in service on the railroads with approximately 8,000 to 10,000 more

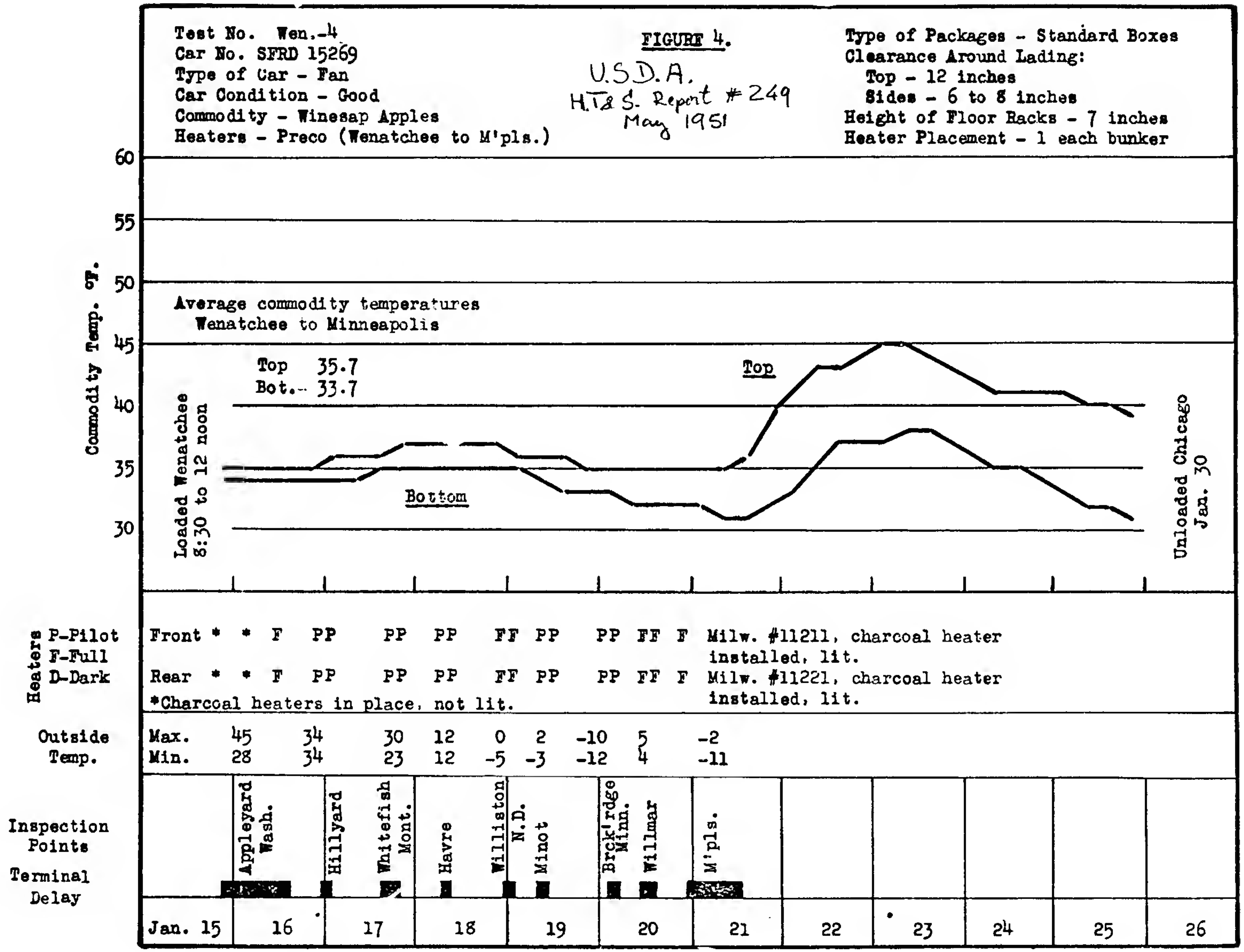
in trucking service throughout the United States. Obviously the Preco heater has met with consumer acceptance and satisfaction for they dominate the market in every way. There may be other types in service here and there but in the aggregate they are relatively few in number.

In adopting the automatic alcohol heater as standard on American Railroads a great improvement has been made in heater service, and through elimination of the many inspection stations formerly required, the railroads have saved thousands of dollars in operating expense. Delays in making inspections have also been eliminated and thus some contribution was made to the program for speeding up freight train schedules.

Progress, however, always exacts some toll. The mechanical refrigerator which is rapidly supplanting the ice bunker car is capable of producing controlled temperatures over a wide range - from zero to seventy degrees Fahrenheit. As time goes on the sales outlet for heaters for refrigerator cars will gradually shrink but a fairly good outlet will still be there for heating insulated box cars and highway trailers. Preco, however, is a very resourceful company and their ability to diversify and come up with other useful products has been demonstrated many times.

Am enclosing copy of the Dvering patent (Figure 1 in Appendix D).

Also ran across an extra copy of USDA test 249 which rather graphically shows that each time a charcoal heater was used in place of an automatic alcohol heater the temperatures in the car quickly rose to undesirable levels (Figure 4 of Test 249 is on page 9).


Test No. Wen.-4
Car No. SFRD 15269
Type of Car - Fan
Car Condition - Good
Commodity - Winesap Apples
Heaters - Preco (Wenatchee to M'pls.)
FIGURE 4.
U.S.D.A.
H.T.& S. Report #249
May 1951
Type of Packages - Standard Boxes
Clearance Around Lading:
Top - 12 inches
Sides - 6 to 8 inches
Height of Floor Racks - 7 inches
Heater Placement - 1 each bunker
Commodity Temp. °F.
60
55
50
45
40
35
30
Average commodity temperatures
Wenatchee to Minneapolis
Top 35.7
Bot. 33.7
Loaded Wenatchee
8:30 to 12 noon
Top
Bottom
Unloaded Chicago
Jan. 30
Heaters
P-Pilot
F-Full
D-Dark
Front * * F PP PP PP FF PP PP FF F Milw. #11211, charcoal heater installed, lit.
Rear * * F PP PP PP FF PP PP FF F Milw. #11221, charcoal heater installed, lit.
*Charcoal heaters in place, not lit.
Outside Temp.
Max. 45 34 30 12 0 2 -10 5 -2
Min. 28 34 23 12 -5 -3 -12 4 -11
Inspection Points
Terminal Delay
Appleyard Wash.
Hillyard
Whitefish Mont.
Havre
Williston N.D.
Minot
Brck'rdge Minn.
Willmar
M'pls.
Jan. 15
16
17
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III. RECOLLECTIONS OF THE CHIEF ENGINEER

A Heater for Railroad Refrigerator Cars

by P.K. Beemer,
formerly Vice President, Engineering
Preco Incorporated

This recounting describes some of the more memorable phases of a successful product development. It was successful by the sound criteria that it made money for the company which undertook the project and that it performed a useful service for the customers. In fact this product was good enough to capture virtually the entire market from several competitors. During a period of 15 years over 80,000 units have been sold at an average price of $70.00 each for a total of about 6 million dollars. During its early years the program was fraught with troubles and failures that cost painfully in dollars, sweat, tears and even a little blood. At no time were there no problems; something always needs solving as long as a product is being made and sold; this product is still being sold and there are still problems.

We are all familiar with new products or radical changes in existing products having resulted from newly perfected materials and technologies. Less spectacular, and possibly sometimes overlooked, opportunities for new products and product improvements also result from the sociological and economic changes that are taking place.

The development of the alcohol-burning heater for railroad refrigerator cars did not come from some new material or new-found knowledge, but became needed because of the inexorable social-economic movement which includes higher wages along with people's desire for and ability to buy better food. Very simply, the railroads could not afford to pay the steadily increasing labor rates to operate the charcoal heaters they had used successfully for many years, because these heaters demanded a lot of attention to keep them going and properly regulated. At the same time there was an increasing market for good-quality fresh fruits and vegetables long distances from the growing areas, in spite of the spectacular growth of the frozen foods industry. Fresh fruit and vegetable transportation requires close temperature control, which includes protection from winter cold.

Before the advent of mechanical refrigeration systems (which are still available in only a small percentage of refrigerator cars) rail shipments of foodstuffs and other commodities

requiring temperature control were made solely in special, insulated box cars with bunkers at each end. In warm weather water ice, which is very economically produced, is dropped into the bunkers for refrigeration; in cold weather portable heaters are put in the same bunkers to maintain safe temperatures for the lading. During both services air is circulated by fans deriving their power from the car wheels.

Portable charcoal heaters had been used by the railroads for nearly a century and are still used on long and medium hauls by the trucking industry, although in trucks also, charcoal is now being replaced by other fuels. Beginning in the early thirties various railroads, the Association of American Railroads, and the U.S. Department of Agriculture investigated and experimented with several types of heaters and fuels to try to gain reduced handling costs and better temperature regulation. This work extending up to the beginning of World War II covered such fuels as charcoal, kerosene, propane, butane and various alcohols. Many forms of manually controlled and thermostatically controlled heaters were tried. From all of this, the most encouraging combination appeared to be a thermostatically controlled heater burning methyl alcohol, CH_3OH, although the answer was not clear-cut and there certainly was not universal agreement among the various investigators. No satisfactory heater design resulted from any of the various efforts.

After World War II, the engineering department of Preco Incorporated was asked to take over a heater development that had been begun by the Pacific Fruit Express Co. Pacific Fruit Express had gone so far as to make several hundred methanol-burning, wick-feed heaters with no temperature control and place them in service. After an encouraging start, troubles had begun to mount, not the least of which was that the heaters wouldn't burn; at that point the PFE management decided to hand the problem to Preco. The managements of both companies believed that relatively little remained to be done---"just add a thermostat, and substitute something for that fibrous asbestos wick that swells and chokes off the fuel flow". As it turned out, the problem was not that simple.

Before beginning any development program it is only logical to define the problem as comprehensively as possible. This includes listing all the requirements and attempting to foresee troubles. In the case being discussed some of the important points were correctly assessed, some were recognized but misunderstood, and some were missed completely until actual field experience brought them out.

For the refrigerator car heater required, the principal specifications and characteristics were as follows, although all of them were not clearly known in the beginning:

1. *Portable, readily handled by one man. Must pass through a 16 x 24 inch refrigerator car icing hatch.*
2. *Heat output about 6000 BTU per hour. Thus two heaters could protect a cargo from freezing in -30°F weather in a car with 200 BTU per hour heat leakage per degree difference.*
3. *Thermostatic control manually adjustable between 30° and 60 °F.*
4. *When on, "pilot" heat output should be as low as practicable.*
5. *Absolutely windproof. The heater must remain lighted even when out on the dock in a winter storm waiting for installation in the bunker.*
6. *Safe. Is used by unskilled labor.*
7. *Operation unaffected by severe shock and vibration.*
8. *Rugged. Will be dropped and banged around in all manner of ways.*
9. *Corrosion-resistant. Life and proper functioning must not be impaired by fuel, moisture or any combination encountered in service.*
10. *Fuel capacity should be sufficient for 50 hours of operation at full burning rate.*
11. *Cost must be as low as possible because the heater has to compete with the low-priced charcoal heaters already available.*
12. *High reliability is essential.*
13. *No noxious products of combustion can be tolerated even when used in a tightly closed car.*
14. *The heaters should be readily stackable, one upon another, to save storage space.*

After due consideration, and some experiments, capillary wick fuel feed was retained over the alternate arrangement of gravity fuel flow regulated by a float valve. Subsequent experience of a competitor proved this a wise decision. The successful wick arrangement was a tight pack of fine spun glass in a cylindrical stainless steel cartridge about 3 inches diameter by 10 inches high, the perforated lower cartridge end being immersed in the fuel and the smoothly trimmed upper end of the fibers being the burning surface.

Flame control was achieved by having the thermostat raise and lower a light weight stainless steel "snuffer plate" over the wick burning surface. Much hard thinking and experimenting

was done to find a snuffer plate configuration that would allow a full flame with a short vertical travel, would establish a reliable small pilot flame when down, and would not extinguish the flame with random motions and positions between.

Early snuffer plate work suggested that the thermostat control should operate between "off" and "on" with a snap action and the first heaters were so constructed. The most feasible temperature-powered motors (thermostat elements) appeared to be either liquid-to-gas filled metal bellows or bonded bi-metal strips. The relatively high energy required by the snap action device led to the choice of the fluid filled bellows. To compensate for altitude changes (up to 8,000 feet) an air filled bellows was added. Thus the first temperature-powered snuffer actuator became a rather formidable package.

While these first units were in service, more was learned in the laboratory and in the field about snuffer plate design and more thought was put into the whole flame control problem. As a consequence, the rather messy "flame holder" in the top of the wick was eliminated, the snuffer plate was modified, and the thermostat device was greatly simplified to a modulating action powered by a spiral bi-metal unit, the energy requirement having been greatly reduced. A very simple (and patentable) manual temperature setting linkage was devised. Weights of all moving parts were kept to an absolute minimum to reduce friction and to reduce wear from the incessant vibration of railroad service. The design proved to be very cheap to produce, and after 15 years of service it appears that the controls will last as long as anyone wants to use them.

Producing a flame from a wick is an ancient art and should not cause much trouble today, however in this product more engineering, quality control, and field service time was spent on wicks than for the combined total of all the other parts and assemblies. Several years were required to learn a few truths that in retrospect seemed elemental and obvious.

The painful history will not be recounted in detail except to say that low burning rates, high burning rates, fires, threatened law suits, heater service failures, lading damage claims, and personal injuries were encountered before all concerned knew how to build and use the heaters properly. Some of the troubles were shown to be solely due to gross carelessness of the operating personnel, however this was not always clear at the time.

Technical investigations and field experience taught the following:

1. For an alcohol fuel and burning rate up to 12,000 BTU per hour the glass fibre wick is overall an excellent way to produce a controlled flame; its life is indefinite.

2. Capillary flow was always able to supply adequate fuel up to the required 10 inch lift.

3. Combustion takes place between vaporized alcohol and air.

4. Vaporization of liquid alcohol has to take place where the liquid is, and where adequate heat can be supplied. This meeting zone is the <u>tips</u> of the closely packed glass fibres.

5. Any appreciable deposit of foreign substance at the tips of the fibres shields the liquid from flame heat thus reducing vaporization, and thus cutting burning rate.

6. Detrimental deposits will form from almost any organic or non-organic substance <u>soluble</u> in alcohol and having a vaporizing temperature much above that of alcohol. This includes nearly all petroleum oils, liquid rust inhibitors and many mineral salts. Thus the alcohol must be kept clean and free of soluble substances.

The first production lots of heaters were made with their steel tanks hot dip galvanized inside and out. A season's operation produced intolerable incrustations of zinc salts on the wick burning surfaces. Competent chemists advised that this could not happen because alcohol would not dissolve zinc. However it was later admitted that with water in the alcohol, acid conditions developed which formed soluble zinc salts. The remedy was to do away with the galvanized coating. Plain steel works fine. A little rust forms but it is virtually insoluble in alcohol, even with water present.

As stated in the beginning, this is not a comprehensive history of a product, but merely a resume of some phases which may induce a designer to look ahead for little hidden problems that can cause big troubles.

IV. EVOLUTION OF ONE DETAIL (THE SNUFFER PLATE)

The Preco heater consists of six major subassemblies, a total of about 100 parts. Each of the subassemblies, chimney, tank, wick, thermostat, fuel gage, and spring hook was designed with as much care and foresight as possible, and each had to be changed in accord with service experience. To follow these changes in detail would require volumes; we shall briefly list the evolution of only one part, taking it as an example of many.

Control of the heat output of the Preco Heater is achieved by a thermostat which raises or lowers a snuffer plate. In its "DOWN" position the snuffer plate covers most of the wick area, leaving only a fraction open for the pilot flame. In its "UP" position the snuffer plate uncovers the wick, is heated by the flame, and reflects heat back into the wick to evaporate more alcohol. These functions are explained in Preco Reports RG2 and RG10 and in U.S. Patent 2,742,318.

The first snuffer plate designed for production is shown on drawing 2G120. In five revisions, designated by change letters, it became 2G120E, then was changed to G4518, and again evolved in four more revisions to G4518D. These four drawings, together with snuffer plate assembly G4520, are shown in Appendix G.

Here are the reasons for the ten revisions of this part, and the release dates of the drawings.

<u>2G120; 2-25-48</u> This first production design was the result of the early experimental work described in Appendix E. Many configurations had been sketched and tried. The flame holder (shown in the patent drawing of the heater) passed through the hole in the center of the plate. The hinge tabs connected the snuffer plate to the lever arm which raised and lowered it.

<u>2G120A; 4-28-48</u> The spot-welded hinge tabs were replaced by tabs folded up from material in the area of the hole. A saving in manufacturing cost justified the expense of issuing new drawings. The new single part took the number of the two-part assembly which it replaced interchangeably. (No tooling had yet been produced for 2G120.)

2G120B; 6-3-48 The hinge tabs now were changed from flat metal "flags" to the shape of half-round channels, to obtain better bearing in the holes of the snuffer arm.

2G120C; 4-25-49 A weight tolerance (18 ± 2 grams) is added to decrease random unbalance of the snuffer arm assembly which now was counterweighted.

2G120D; 5-2-49 A curled-up rim is now added to prevent distortion of the snuffer plate by mishandling, which occurs mainly in extinguishing the pilot flame. The weight is increased from 18 to 19 grams to allow for the rim material.

2G120E; 6-7-50 A quarter inch slot, from the central hole to the area near the rim, is added. This was a major revision, the result of some very hard experience. The first quantity lots of about 1,000 heaters had gone into service in the winter 1948-49 and performed quite well. There had been some complaints about "crusts" on the wick surface. To overcome the crusts two steps were taken: the oil used in the manufacture of the glass fiber wicking was completely removed by baking the wick assemblies, and the heater tanks were very thoroughly inspected and cleaned after galvanizing to remove all traces of galvanizing flux which was believed to be soluble in methanol.

About 4,000 more heaters were sold in 1949 and gave more trouble with crusts in spite of the more careful manufacturing methods. Preco took two forceful, courageous steps to overcome the trouble: it analyzed the new crusts, found they consisted of zinc salts, and decided to remove all galvanizing from all heaters which had been sold. However, this could only be done after the heater season, in the spring and summer of 1950. Meanwhile Preco persuaded its customers to remove the crusts by brushing the wick surfaces after each round trip. The flame holder in the center of the wick was an obstacle to brushing. Therefore, Preco people were dispatched to all centers of heater use to modify the heaters in the field. They removed the flame holder and cut a slot in the snuffer plate. Removal of the flame holder permitted brushing the wick surface and also more positive extinction by slipping an extinguisher plate over the wick, beneath the snuffer plate. The object of

the slot was simply to increase the pilot flame so that it would not go out without the flame holder. This operation and the removal of galvanizing from all heaters, together with the necessary rework, cost over $200, 000, but it kept Preco in the heater business.

G4518; 4-10-51 This was a redesign incorporating the features of previous snuffer plates, plus better protection of the pilot flame against wind and a tab which limited the angle of the snuffer plate relative to the snuffer arm. The plate is connected to the arm by a pin which passes through two of the holes in the flame shield and is retained by bending the lateral tabs of the flame shield down. We have now replaced one piece by three. A new part number is needed because the revised design is not interchangeable with the older design. The assembly is shown on G4520.

G4518A; 1-7-52 The slot no longer extends all the way out to the circumference; this provides greater stiffness and protects the plate from deformation by careless handling.

G4518B; 3-3-52 The curled-up rim is made stronger. It is also flattened down for 1/4 inch at one point to permit drainage of the water which sometimes condensed on the snuffer plate.

G4518C; 9-3-52 Only the material specification is changed from "stainless Type 321 or 347" to "Preco Spec. S 352". The purchasing department had requested more leeway in using other types of stainless because stainless was scarce during the time of the war in Korea.

G4518D; 3-21-62 The material specification is changed again to "Stainless Steel Type 316, 321, or 347". High output heaters had been sold and in these the higher temperatures produced scaling and intergranular corrosion in some types of stainless steel.

While this series of changes modified the technical specifications of the snuffer plate, the forms and clerical procedures also were changed. Each change of procedure upset the habits of many people and had to be carefully considered and sold.

The early drawing numbers "2G120D" were replaced by numbers of the type "G4518C". The first numeral had indicated drawing size. It was eliminated because occasional drawing size changes had confused customers who might order part 2G118 and receive 1G118, the same part, redrawn on a smaller sheet. The much higher number 4518 instead of 120 results from the change to one consecutive series of numbers for all drawings instead of series starting at "1" for each product line (heaters, fans, bunkers, etc.), each line identified by a prefix (G for heaters).

Changes in the change procedure itself can also be inferred from the title blocks; they were made in an effort to keep the necessary records in a less cumbersome and less costly manner.

V. SOME PROBLEMS ENCOUNTERED IN DESIGNING THE HEATER

1. Thermostat. The main line of this development is explained in Mr. Beemer's recollection (Section II) and some of the details appear in Section IV.

2. Tank. (See tank assembly drawing, Appendix J.) The tank vent proved to be more troublesome than expected. The top of the tank is heated by radiation. When a small quantity of methanol is sloshed against the hot top, it evaporates and creates a pressure surge which may drive liquid methanol up through the wick faster than it can evaporate there.

A special vent structure, protected against back-flash by wire screens, is now used on the heater. A large diameter stainless radiation shield was added to prevent the tank top from seeing the flame. The legs which connect the chimney to the tank were arranged to receive a minimum of radiation from the flame and to radiate absorbed heat to the surrounding air.

The "ears" which serve to attach the heater to the bunker were changed from the forgings shown in the patent drawing to stampings. These stampings provide more area for projection welds.

3. Wick. In the early stages of design the questions were: how high methanol could be lifted by a wick without decrease of heat output; whether a solid wick, which is much easier to install, could be used in place of the original tubular wick; what size was required; what material could be used?

After a year or two of production, many other problems had appeared: there had been flames inside the fuel tank; these were blamed on passage of flame through openings in the wick. Methods of checking wicks for tight packing had to be devised. Wicks had risen up above their normal position and produced very large flames. To prevent this, the crimps in the wick jacket, shown in the parts list illustration, were specified.

Clogging of wicks is mentioned in Section IV. Cleaning of wicks removed from galvanized tanks, before installing them in bare steel tanks, presented a serious problem. Soaking in dilute hydrochloric acid followed by

thorough flushing with distilled water was used. One batch of wicks was removed from the hydrochloric soaking on a Friday and not flushed until Monday. It developed a new kind of crust which had to be traced to this batch and incident.

4. Spring Hook. Two spring hooks are used to fasten the heater to the wire screen or perforated plates which line refrigerator car bunkers. The heater weighs about 70 pounds when filled. The spring hooks are tested to 650 pounds pull. Charcoal heaters had been fastened by chains and harness snaps. The spring hook was designed as an improvement on this. The first design had an open spring; this turned out to be awkward to handle with mittens. The next design had a one-piece housing, and an open hook. It worked only when carefully attached to the bunker lining. To overcome this problem, a hook with closure was designed. The closure was formed by a spring tongue. Instead of depressing the spring tongue, some heater men twisted them off, which was easier. The present latch bolt closure was then designed.

5. Fuel Gage. Early production heaters were equipped with a dip-stick, attached to the filler cap. Customers then demanded a fuel gage; a commercially available gage, designed for an automobile of about 1930, was specified. This gage was not satisfactory, partly because of corrosion but mainly because the cork float deteriorated in methanol. Preco then designed a new fuel gage, made of stainless steel, with a large more legible dial, and a commercially available polyethylene bottle as the float.

6. Chimney. After the flame holders had been removed in the emergency campaign of 1949-50, the pilot flame was more susceptible to extinction by air drafts. Rather elaborate wind-shields were then added to the chimney assembly.

The bail had given some troubles by being too hot to handle after resting against the chimney. It was relocated, and its attachment to the chimney was improved.

7. Unsolved Problems.

a) The fuel gage cannot distinguish between an empty tank and one filled with a quart of methanol because it takes that much to lift the float. An inexpensive way to overcome this would be a help to heater users.

b) Leaks developed in some heaters. Examination by competent metallurgists established that the leaks came through cracks which had all the marks of stress-corrosion cracks. However, all attempts to duplicate formation of the cracks in the laboratory were unsuccessful, and no remedy was developed. Occasional cracks and leaks still occur.

VI. REFERENCES

1. Car Builder's Cyclopedia, Simmons-Boardman, New York.

2. Redit, W. M., and A. A. Hamer, "Protection of Rail Shipments of Fruits and Vegetables", U. S. Department of Agriculture, Agriculture Handbook No. 195, July 1961.

3. Beemer, P. K., and F. C. Lindvall, "Dynamically Stable Spring Suspension for Railway Cars and Motor Coaches", SAE Journal, Vol. 50, No. 12, pp. 521-527 (December 1942).

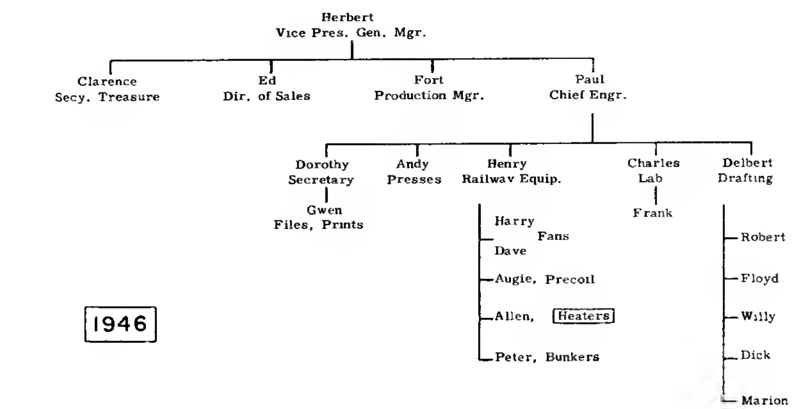
4. AAR-USDA Tests No. 12, 13, 14, 15 under Heater Service in December 1946 and January 1947, Association of American Railroads, Chicago.

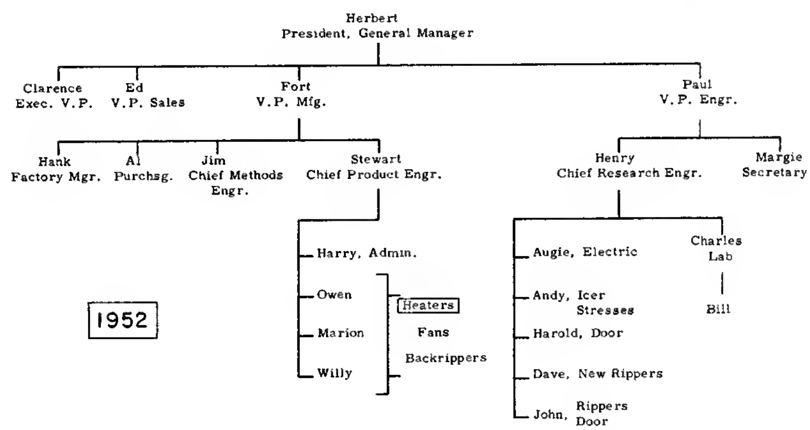
5. Manual of Standard and Recommended Practices, Association of American Railroads, Chicago, (page L-65-1958).

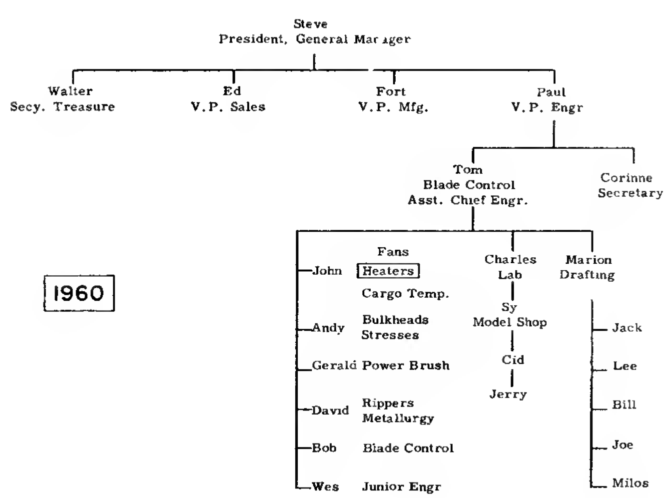
6. Transportation of Agricultural Commodities in the United States. A Bibliography of Selected References, U. S. Department of Agriculture, Miscellaneous Publication No. 863.

APPENDIX A

PARTIAL ORGANIZATION CHARTS OF PRECO INCORPORATED SHOWING THE ENGINEERING LINE-UP AND RESPONSIBILITY FOR THE HEATER AT THREE DATES

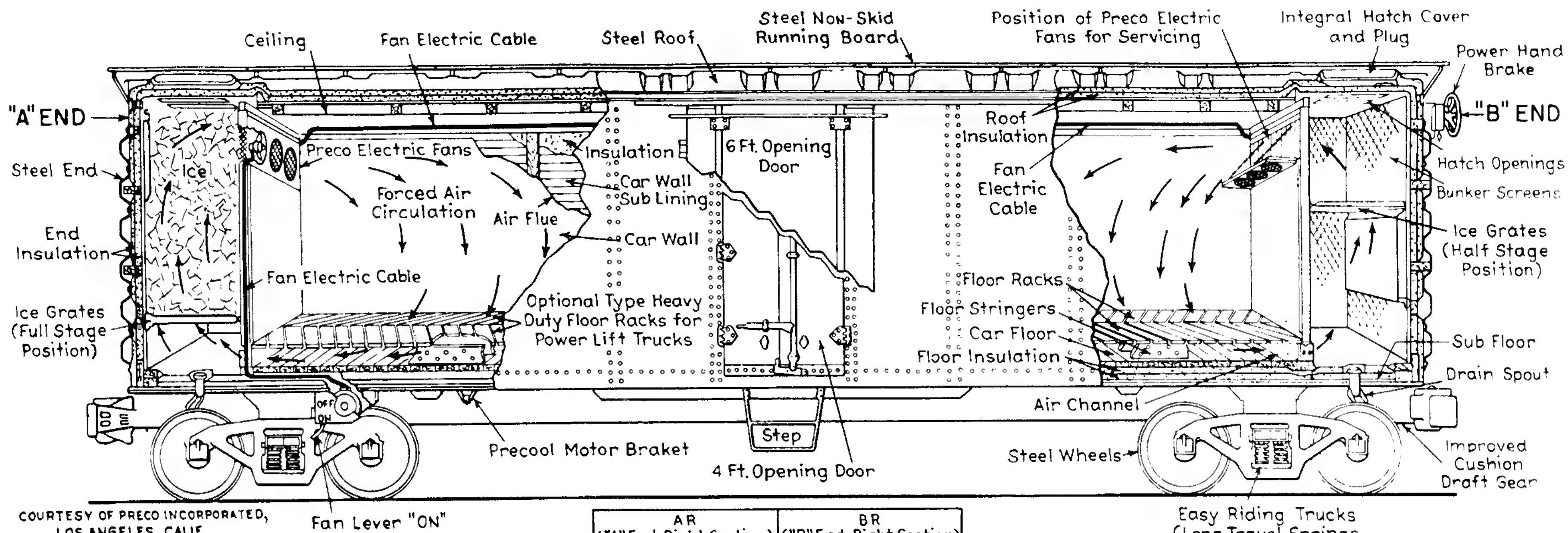




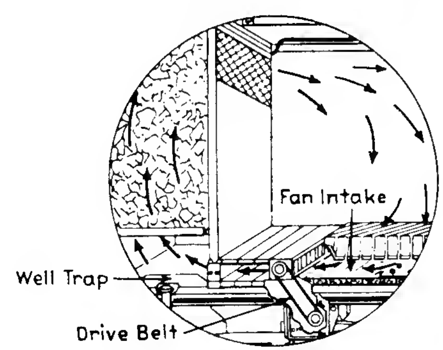


APPENDIX B

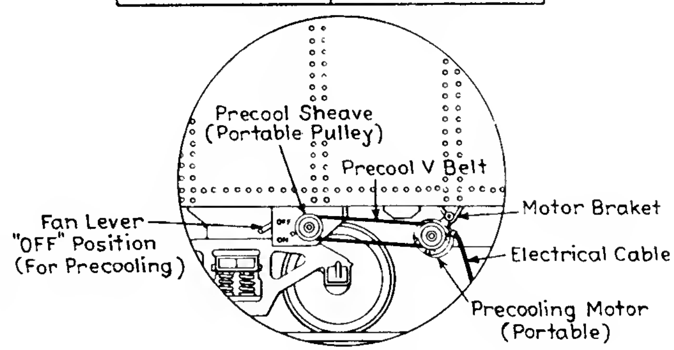
REFRIGERATOR CAR DRAWING



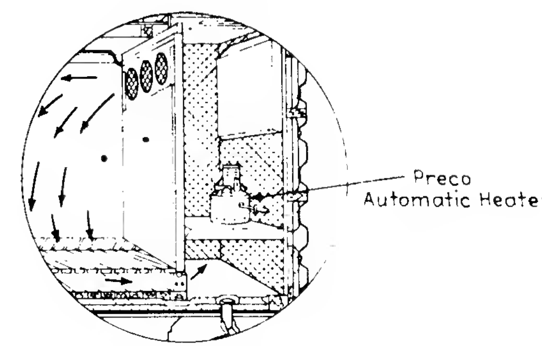
"A" End			"B" End (Brake End)
	AR ("A" End-Right Section)	BR ("B" End-Right Section)	
	AL ("A" End-Left Section)	BL ("B" End-Left Section)	



PRECO FLOOR TYPE FANS



PRECO PRE-COOLING METHOD



USE OF PRECO AUTOMATIC HEATER

Design for a modern ventilated refrigerator car recommended by the refrigerator car committee of the United Fresh Fruits and Vegetable Association and U.S. Railroad refrigerator car lines. Showing stage icing, fixed bulkheads, floor and electric type forced air circulating fans, pre-cooling method and use of automatic heater as developed by Preco Incorporated.

APPENDIX C

REPLACEMENT PARTS LIST WITH CUTAWAY VIEW

PRECO AUTOMATIC HEATER

MODELS GB6, GB5, GB4, GB3, AND GF2

REPLACEMENT PARTS PRICE LIST

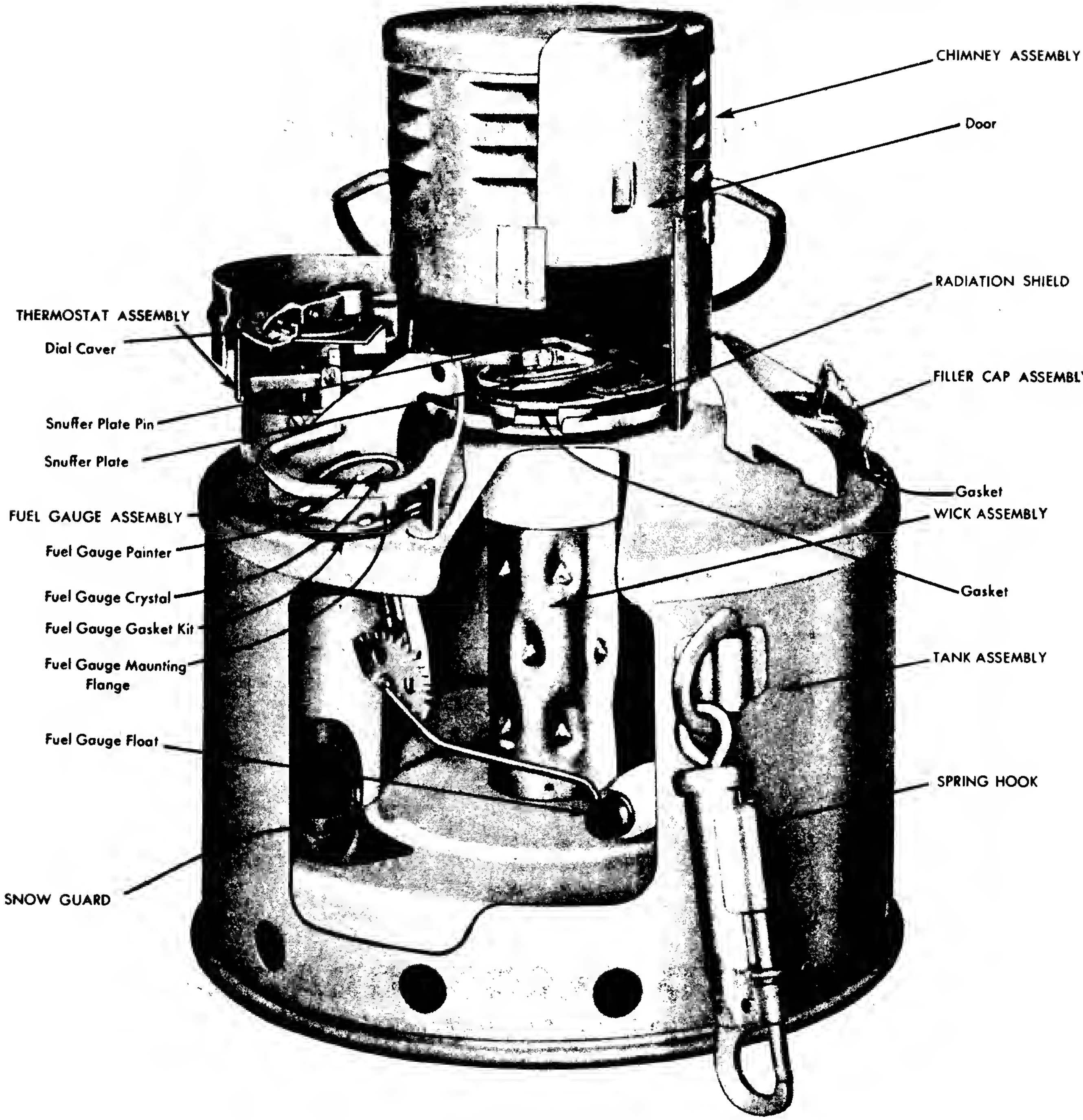
THIS LIST IS IMPORTANT

It should be consulted before placing orders to ossure obtaining proper parts for your PRECO AUTOMATIC HEATERS.

PRECO INCORPORATED
6300 East Slauson Ave., Los Angeles 22, Calif.

PRECO AUTOMATIC HEATER

MODEL GB6



PRECO AUTOMATIC HEATER

MODELS GB6, GB5, GB4, GB3, AND GF2

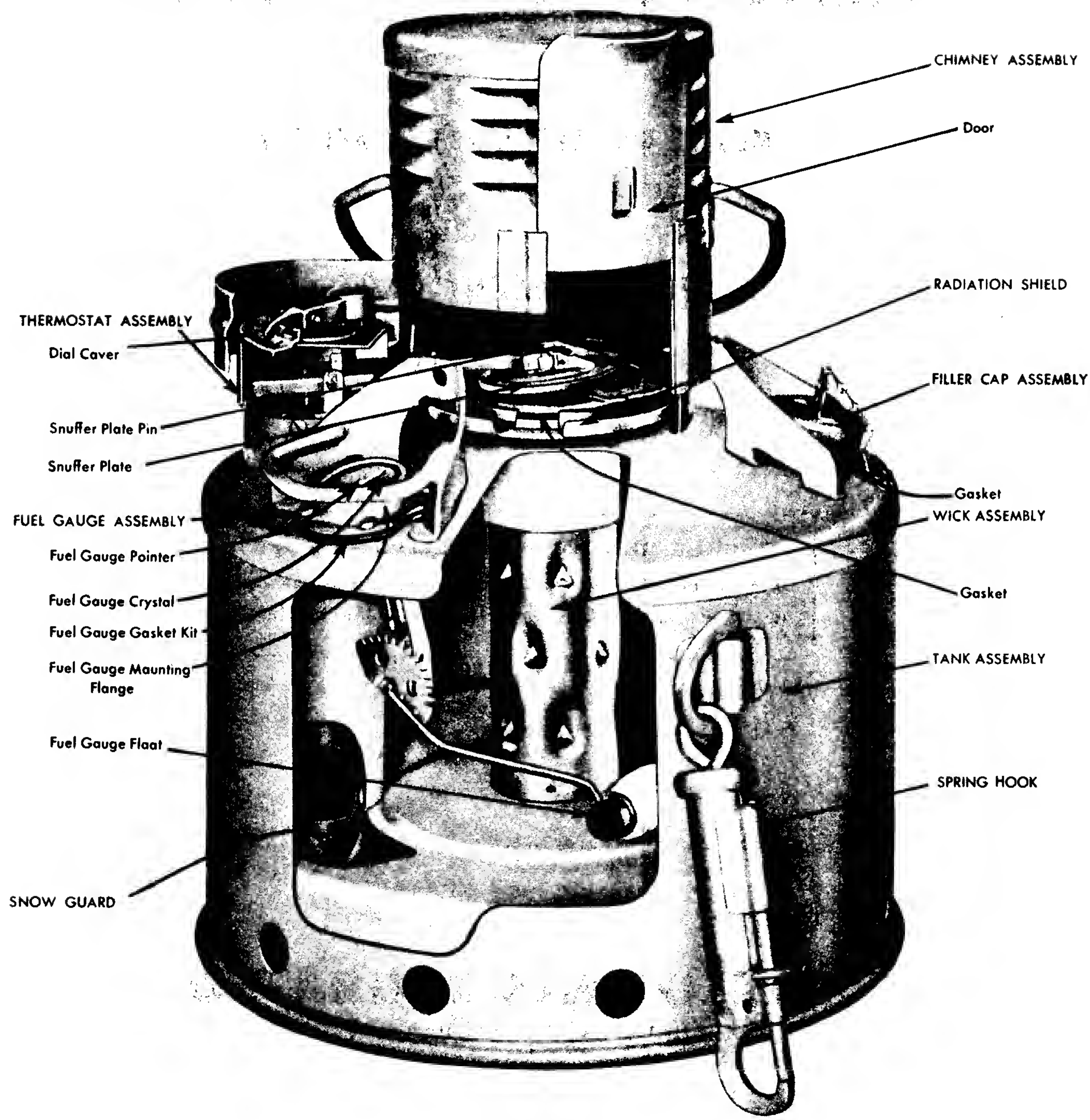
REPLACEMENT PARTS
PRICE LIST

THIS LIST IS IMPORTANT
It should be consulted before placing orders to assure obtaining proper parts for your PRECO AUTOMATIC HEATERS.

PRECO INCORPORATED
6300 East Slauson Ave., Los Angeles 22, Calif.

PRECO AUTOMATIC HEATER

MODEL GB6



TO ASSURE OBTAINING THE CORRECT PARTS FOR REPLACEMENT, THE FOLLOWING SHOULD BE OBSERVED:

1. All assemblies and sub-assemblies, listed below by number and name, may be identified and located in the illustration on opposite page.
2. Complete assemblies are shown in **HEAVY TYPE.** Sub-assemblies follow immediately in lighter type.
3. When ordering parts, be sure to show quantity required, part number, and name and model number of heater for which intended.
4. Hardware required is shown immediately following the parts list.
5. When ordering hardware, be sure to show quantity required, hardware description, including dimensions, part name and number for which intended.
6. Prices F.O.B. Preco Plant, Los Angeles; terms net 30 days. All prices subject to change without previous notice.

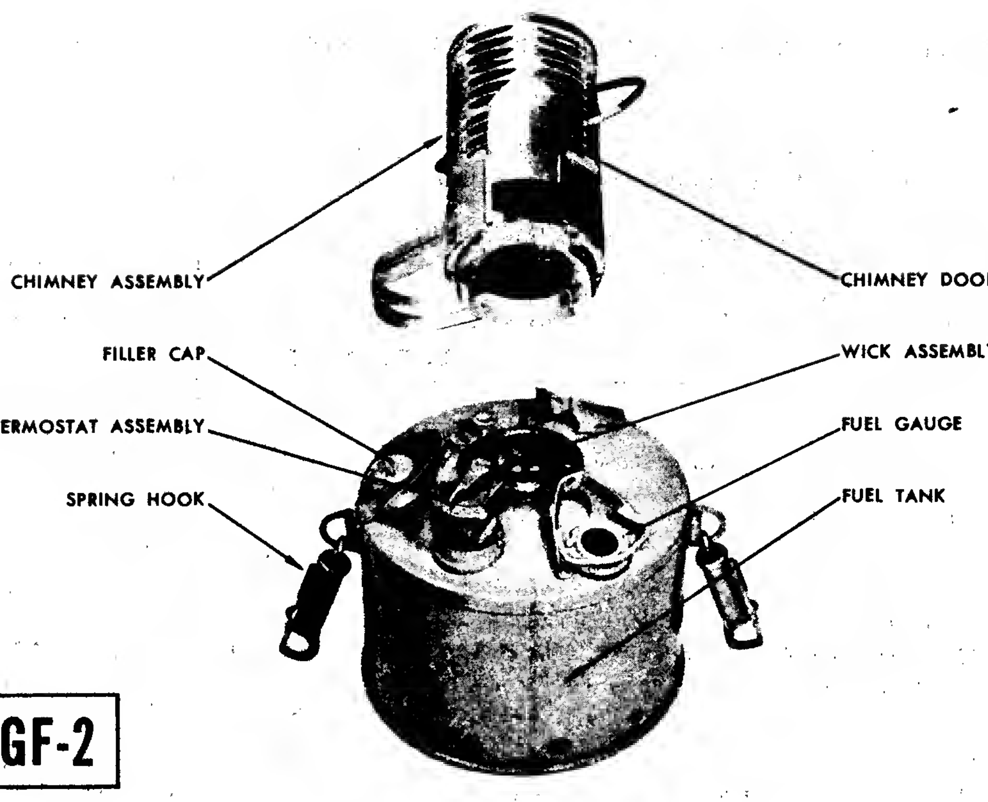
PARTS LIST

PART NAME	PART NUMBERS BY MODELS GB6	GB5	GB4	GB3	PRICE
CHIMNEY ASSEMBLY (complete with door, nuts & bolts)	G4743	G4743	G4743	G4743	$7.50
Door	G4599	G4599	G4599	G4599	.45
FILLER CAP ASSEMBLY (complete with Gosket, Chain & Cotter Pin)	G5796				1.75
		G3031	G3031	G3031	.35
Gasket	G5788				.10
Gasket		G4029	G4029	G4029	.10
FLAME EXTINGUISHER	G5269	G5269	G5269	G5269	.45
UNIT EXCHANGE FUEL GAUGE (Per Bulletin H-2)	***G7389***	***G7389***	***G7389***	***G7389***	***4.75***
FUEL GAUGE ASSEMBLY (complete with gaskets, screws & washers)	G4482	G4482	G4482	None	6.25
Bezel Ring	None	None	G4031	None	.40
Crystal	G4494	G4494		None	.35
Crystal			G4030	None	30
Float Kit Assembly (complete with cap, gasket & plug)	G7309	See Note	See Note	None	.30
Float Replacement Kit (complete with float, cap, gasket, arm and drawing)	G9958	G9958	G6099	None	.85
Gasket Kit (complete with screws, washer & spring)	G4745	G4745		None	1.00
Gasket Kit (complete with screws & washers)			G4744	None	.80
Mounting Flange	G4493	G4493		None	.50
Mounting Flange			G3913	None	.60
Pointer	G4492	G4492	None	None	.15
Spring	G4575	G4575	None	None	.15
RADIATION SHIELD	G3843	G3843	G3843	G3843	1.00
SNOW GUARD	G4017	G4017	G4017	G4017	.10
SPRING HOOK ASSEMBLY	G3987	G3987	G3987	G3987	2.75
Replacement Spring Catch (1953 GB6 and previous models)	G5208	G5208	G5208	G5208	.20
TANK ASSEMBLY (Mod. GB3 requires G4482 Fuel Gauge Assembly and G5796 Filler Cap Assembly. Mod. GB4 and GB5 require G5796 Filler Cap Assembly).	G5811	G5811	G5811	G5811	33.00
UNIT EXCHANGE THERMOSTAT ASSEMBLY (Per Bulletin H-1)	***G6100***	***G6100***	***G6100***	***G6100***	***12.00***
THERMOSTAT ASSEMBLY (complete with screws & washers)	G6100	G6100	G6100	G6100	19.50
Snuffer Plate and Pin	G4742	G4742	G4742	G4742	.90
Snuffer Plate Pin	G4522	G4522	G4522	G4522	2.50/C.
Dial Cover	G4527	G4527	G4527	G4527	.30
WICK ASSEMBLY (complete with gasket)	G4739	G4739	G4739	G4739	11.50
Gasket	G3955	G3955	G3955	G3955	.15

Note: Use Float Replacement Kit

HARDWARE REQUIREMENTS

CHIMNEY ASSEMBLY G4743	
3 Machine Screw Nuts 5/16-18 Square	$2.00/C.
3 Cap Screws 5/16-18 x 3/4 Hex Head	2.00/C.
3 Lock Washers #1218 Shakeproof	.25/C.
FUEL GAUGE ASSEMBLY G4482	
5 Self Tapping Screws No. 10-32 x 3/4 Round Head, Parker Kalon Type "F"	.55/C.
5 Fibre Washers A. R. Hardware No. 1256	.50/C.
HINGE PIN G4740	
1 Cotter Pin 1/16 x 3/8	.20/C.
RADIATION SHIELD G3843	
6 Self Tapping Screws No. 10-32 x [illegible] Binding Head, Parker Kalon Type "B"	.50 C.
SNUFFER ARM ASSEMBLY G4521	
2 Cotter Pins 1/16 x 3/8	.20/C.
THERMOSTAT ASSEMBLY G6100	
2 Self Tapping Screws No. 10-32 x 1/4 Binding Head, Parker Kalon Type "B"	.50 C.
2 Lock Washers No. 1210 Shakeproof	.25 C.



MODEL GF-2

PRECO AUTOMATIC HEATER • REPLACEMENT PARTS PRICES

PART NAME	PART NO.	PRICE EACH
CHIMNEY ASSEMBLY (with door nuts & bolts)	G11078	$13.00
Chimney Door	G4599	.45
FILLER CAP (w/Gasket, Chain & Cotter Pin)	G5796	1.75
Gasket	G5788	.10
FLAME EXTINGUISHER BOTTLE	G11060	.45
EXCHANGE FUEL GAUGE (REBUILT)	G7389	4.75
FUEL GAUGE (w/Gaskets, Screws & Washers)	G4482	6.25
Crystal	G4494	.35
Float Kit (w/Cap, Gasket & Plug)	G7309	.30
Gasket Kit (w/Screws, Washer & Spring)	G4745	1.00
Mounting Flange	G4493	.50
RADIATION SHIELD (2 REQUIRED)	G11084	.90
Radiation Baffle (2 Required)	G9916	.90
SPRING HOOK	G3987	2.75
FUEL TANK	G5811	33.00
EXCHANGE THERMOSTAT ASSY. (REBUILT)	G6100	12.00
THERMOSTAT ASSEMBLY (NEW)	G6100	19.50
Thermostat Adapter (2 Required)	G9911	.10
Snuffer Plate & Pin	G4742	.90
Snuffer Plate Pin	G4522	2.50/C.
Dial Cover (For Thermostat Control)	G9907	.30
WICK ASSEMBLY	G9875	17.50
"O" Ring Gasket	AN-6227-38	.40

SEE PREVIOUS PAGE FOR HARDWARE

1. All prices F.O.B. Preco Plant, Los Angeles, California. Terms — Net 30 Days.
2. No material is to be returned for credit or on "Rebuilt Exchange" basis without written approval from Preco Incorporated.

PRICES SUBJECT TO CHANGE WITHOUT NOTICE • EFFECTIVE JANUARY, 1959

Patented Canada 1952
U.S. and other patents applied for

Form No. PH-854-159
The name PRECO is reg. U.S. Pat. Off.

Litho in U.S.A.

APPENDIX D

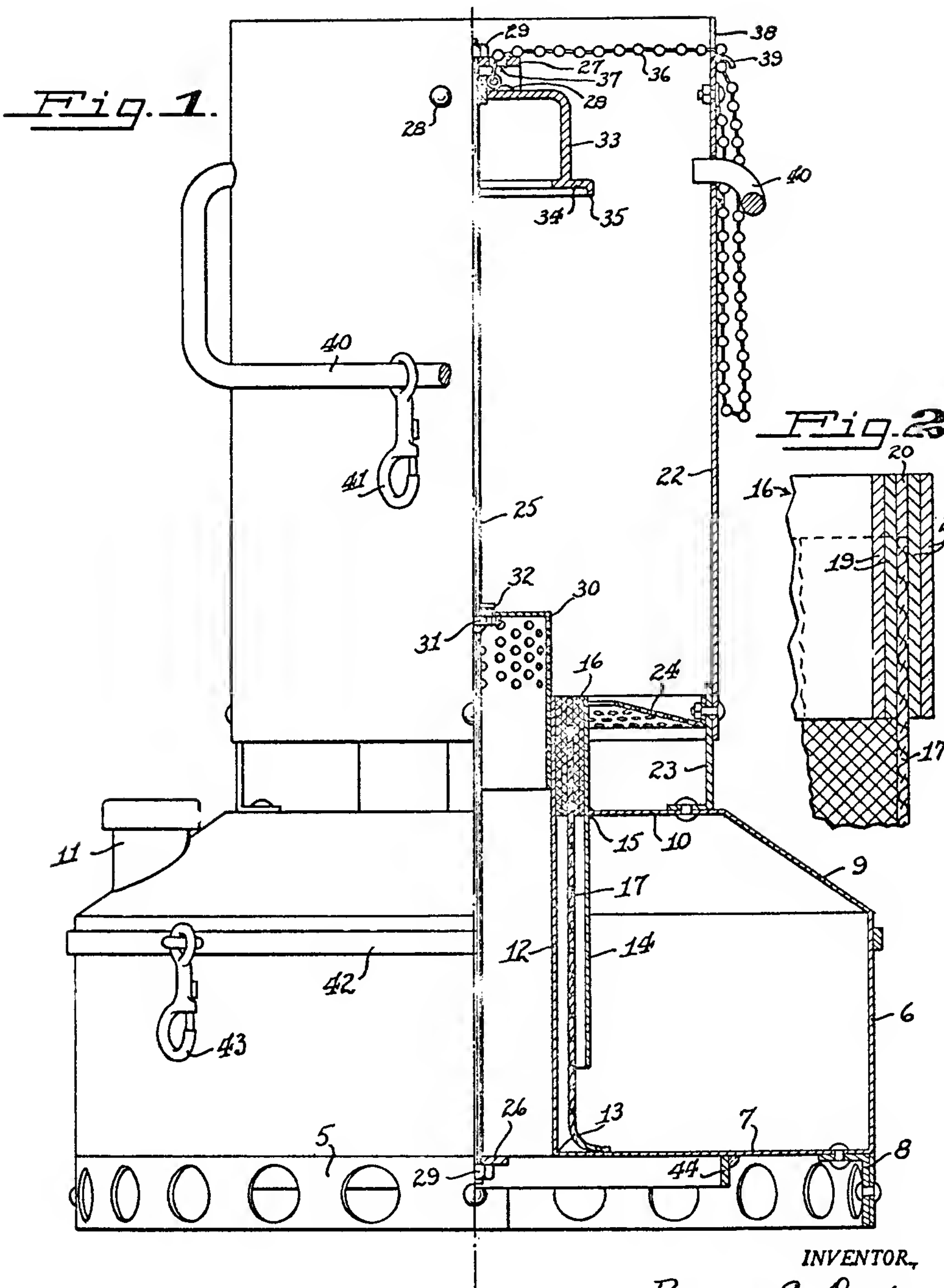
PATENTS:

2,433,829
2,717,590
2,742,318

Jan. 6, 1948. R. A. DOERING 2,433,829

HEATING STOVE

Filed June 28, 1944



INVENTOR,
Raymond A. Doering
BY
William F. Booth Jr.
ATTORNEY.

THERMOSTATICALLY CONTROLLED WICK TYPE HEATER

Filed Nov. 7, 1949 6 Sheets-Sheet 1

FIGURE A

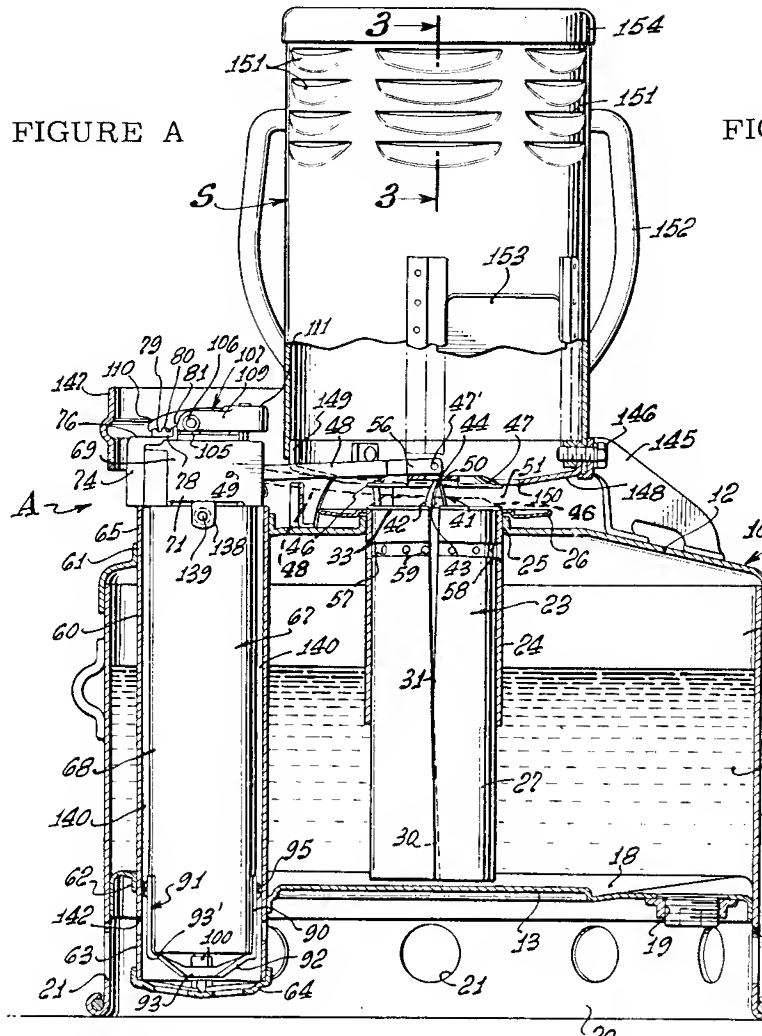


FIGURE B

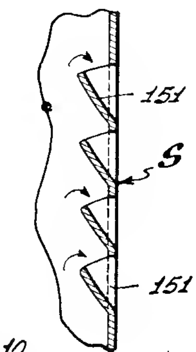


FIGURE C

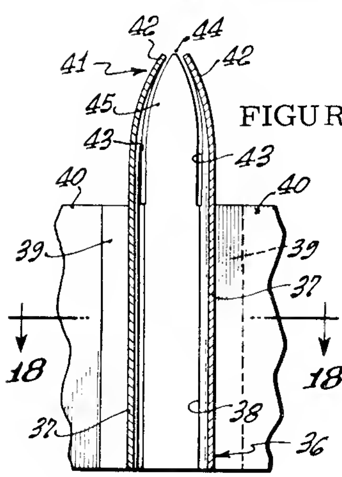


FIGURE D

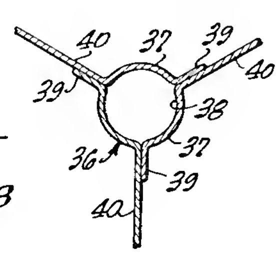
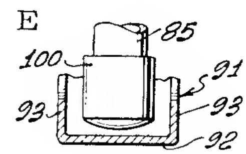


FIGURE E



ALLEN M. STELLE
PAUL K. BEEMER
HENRY O. FUCHS
INVENTORS.

BY

Barkelew & Scantlebury
ATTORNEYS.

United States Patent Office

2,742,318

Patented Apr. 17, 1956

2,742,318

THERMOSTATIC CONTROL UNIT

Allen M. Stelle, San Marino, Paul K. Beemer, Pasadena, and Henry O. Fuchs, Los Angeles, Calif., assignors to Preco Incorporated, Los Angeles, Calif., a corporation of California

Original application November 7, 1949, Serial No. 125,944, now Patent No. 2,717,590, dated September 13, 1955. Divided and this application March 16, 1951, Serial No. 215,972

12 Claims. (Cl. 297—16)

The present invention has to do generally with thermostatic control units, and is more particularly concerned with units especially well adapted to control the burners of heating devices.

This application is a division of our co-pending application entitled Thermostatically Controlled Heater, filed November 7, 1949, Serial No. 125,944, now Patent No. 2,717,590.

The invention is appliable with particular advantage to wick-type burners of heaters used to control the temperature of produce-laden railroad cars and trucks. We will therefore discuss and describe it in that environment, but it will be understood this is in no way to be considered as limitative on the invention.

Heaters used in produce-car and truck heating, are frequently exposed to extremely severe service conditions, and yet, to be satisfactorily effective, they must promptly be responsive to temperature changes—in other words they must be rugged and sturdy and yet the thermostatic control must have a degree of sensitivity which usually demands mechanism of a delicateness rendering it unable to withstand harsh service conditions.

It is necessary that the thermostatic control be as nearly unfailing in performance as possible, for great economic loss may result from temperature conditions (high or low) which have deteriorative effect on produce. A special need for insuring unfailing performance during long periods of hard use, arises from the fact that produce cars are inaccessible to attendants during much of their time in transit. Therefore there is great opportunity for cargo-damage which could be avoided were the thermostatic controls to be under constant observation and accessible for immediate repair or replacement upon discovery of a failure or of a weakness which might be expected to result in failure.

It is therefore among the major objects of our invention to provide a thermostatic control which is sufficiently rugged and strong to withstand extremely severe service conditions, yet one which is relatively sensitive to surrounding temperature conditions, relatively quick-acting in its controlling response to changes in temperature, and is, within all reasonable limits, unfailing in performance.

It is also an object of the invention to provide a thermostatic control unit of such simplified construction that its fabrication and assembly costs are held to a minimum.

Other objects and features of the invention will be made apparent in the following detailed description, reference being had to the accompanying drawings, in which:

Fig. 1 is a medial section, partly in broken-away elevation, through the thermostatic control unit, the section being taken on line **1—1** of Fig. 2; the view also showing fragments of supporting structure (not a part of the present invention) for the unit;

Fig. 2 is a top plan view of Fig. 1, partly broken away section;

Fig. 3 is a section on line **3—3** of Fig 1;

Fig. 4 is an exploded view of a portion of a snap-over spring assembly which may be incorporated in the device;

Fig. 5 is a fragmentary elevation of the lower end of Fig. 1, as viewed from the right thereof;

Fig. 6 is a section on line **6—6** of Fig. 1, except that it shows the control crank arm and its operating rod moved to positions other than those they occupy in Fig. 1;

Fig. 7 is a view similar to Fig. 6 but showing the control mechanism in "off" position;

Fig. 8 is a section on line **8—8** of Fig. 1;

Fig. 9 is a section on line **9—9** of Fig. 1;

Fig. 10 is a detail section on line **10—10** of Fig. 1;

Fig. 11 is a longitudinal medial section through a variational form of thermostatic control unit, showing also environmental structure which supports the unit;

Fig. 12 is a top plan view of Fig. 11, except that the supporting structure is omitted;

Fig. 13 is a section on line **13—13** of Fig. 11;

Fig. 14 is a fragmentary section on line **14—14** of Fig. 13; and

Fig. 15 is a detached and longitudinally contracted view of a portion of the torque transmitting unit of the device.

As stated in the introduction, the thermostatic control unit A is particularly well adapted for use in connection with the control of wick-burners of heating devices, though not limited to such use. Accordingly, for purposes of illustration, only, we have shown a wick-flame snuffer as being connected to and movable by the thermostatic control element, the snuffer being of a type to regulate or snuff the flame from an annular wick burner such as is shown in the aforementioned co-pending application.

Thus, a flame regulating member is here shown in the form of an annulus **46** having a down-turned peripheral flange **47** (Figs. 1 and 2), but, as noted above, this portion of the showing is not to be taken as indicating that the control element of the thermostatic control unit has to be connected to any particular regulating member, nor that the claims are limited to such connection. The flame regulators and snuffers here illustrated, are claimed in our co-pending application entitled Flame Snuffer for Wick-Burners, filed March 16, 1951, Serial No. 215,971.

Annulus **46** is pivotally mounted at **47'** on the fork-arms **56** of the control element of unit A, said element being in the form of a main arm **48** of inverted channel cross-section. Arm **48**, in turn, has pivotal mounting on shaft **49** which supports the annulus so its bore **50** is substantially coaxial with the cylindrical burner-wick (not shown) which underlies it. When annulus **46** is in the dotted line position of Fig. 1 it covers the outer annular or main-burner portion of said wick and thus maintains that portion of the burner extinguished, though the bore of the annulus allows the central portion of the burner to remain lighted and thus serve as a pilot burner. Movement of arm **48** which varies the spacing between the wick and annulus, serves to regulate the height of the main burner flame. We will more definitely locate and describe the support of shaft **49**, at a later point in the description.

The supporting means for unit A comprises no part of the present invention, but, to clarify certain points made later in the specification, certain elements thereof are shown and will be briefly described. Thus, a vertical sleeve **60** is illustrated as extending through a heater-dome neck, fragmentarily illustrated at **61**. The upper end **65** of the sleeve serves to support unit A in annularly spaced relation thereto, as at **140**.

Unit A includes a housing generally indicated at **67**; made up of cylindrical jacket **68** (Figs. 1 and 3) and the

generally rectangular shell **69** which is in the form of an inverted channel member having a top wall or web **70** and vertical side walls or flanges **71**. Side walls **71** have segmental horizontal flanges **72** welded at **73** to jacket **68**, and it is these walls which support pivot-shaft **49**, previously spoken of, whereby arm **48** is mounted for swinging movement. Walls **71** extend chordally beyond jacket **60** (Fig. 7) and are connected at one side of the jacket by the end wall **74** which is arcuate as viewed in plan, the lower edge of wall **74** having a struck-up ear **75** to act as an arm stop. Horizontal scale-plate **76** is integral with wall **74** and carries scale marks or calibrations **77** (Fig. 2). The marks indicate temperatures at which the thermostat, to be described, may be selectively regulated to actuate snuffer **46**. Scale-plate **76** has a vertically extending latching flange **78** provided with alternate notches and projections **79** and **80**, respectively, corresponding with certain of the marks **77**, this flange being arcuate, as viewed in plan, and being concentric with respect to jacket **68**. At one end of the flange **76** is a stop lug **81**, projecting higher than do projections **80** (Fig. 8) while at the other end of the flange is an "off" projection **82** of the same height as, but of greater arcuate extent than, projections **80**. At the outer end of and extending above projection **82**, is arranged a stop member **83** secured to a side wall **71** and **83'**.

The lowermost end of tube **68** houses the bi-metallic, coiled-band type of thermostatic element **84** (Figs. 1 and 9) having the resilient qualities usual to such elements. The inner end of the coil is operatively connected to actuating rod **85** by extending it through rod-slot **86** which opens to the bottom of the rod. The outer end of the coil is reduced slightly in width to form a tab **87** which is turned angularly through the relatively wide jacket-slot **88** and through the relatively closely fitting slot **89** in one of the legs **90** of calibration adjustment member or yoke **91**. The legs **90** fit the jacket **68** at diametrically opposite sides thereof, while the stirrup portion **92** of the yoke is spaced below the end of jacket **18** and freely admits air from below to the bore of the jacket and, of course, to the spaces between the coils of element **84**. The stirrup has horizontally spaced vertical flanges **93** (Figs. 1 and 10) and has horizontal shoulders **93'** which limit the downward movement of the thermostat element **84**. Legs **90** have horizontal slots **94** through which attachment screw **95**, threaded into jacket **68**, extend. After loosening screws **95**, member **91** may be rotated (within the limits established by the circumferential extents of slots **88** and **94**) to act on thermostat tab **87** and hence on the entire element **84** in a manner to rotate rod **85** and the elements carried thereby. This mechanism is used for setting the thermostat to the calibrations **77**, as will appear.

The jacket **68** is preferably pressed in at the side opposite tab **87** to form elongated lugs **96** which hold element **84** against excessive bodily side shift such as might clear tab **87** from slot **89**.

Thermostatic coil **84**, through its association with the jacket **68** and stirrup **92**, supports rod **85** from its lower end. The upper end of the rod has universal joint connection **97** (Fig. 1) with the socketed boss **98** carried by disk **99**. Stirrup **92** opposes the head **100** which is secured to the lower end of rod **85** to pinch the slotted rod about the coil end **86** and thus retain the coil in position. Stirrup **92** prevents rod **85** from dropping a sufficient distance to disengage the ball and socket joint **97** in the event the stiffness of the coil is insufficient to hold the rod up. The stirrup and its flanges also limit the transverse movement of the lower end of the rod, but the limitation is not close, for head **100** has fairly free capacity for bodily transverse displacement.

Disk **99** is mounted for rotation with respect to housing portion **69** by reason of its particular mounting in top-wall **70**. Said wall is provided with a bore **101** which is concentric with jacket **68**, and from this bore there extend diametrically opposite notches **102'** (Fig. 3). Disk **99** has a portion **102** adapted to have rotational bearing in bore **101**, ears **103** extending radially from bearing portion **102** and lying just beneath housing-top **70**. Above the plane of wall **70**, the disk has a diametrically enlarged portion presenting an annular flange **104** spaced from ears **103** by the common thickness of wall **70** and disk portion **102**. This disk is assembled with the housing by rotating it 90° from the position of Fig. 3, lowering it until portion **102** enters bore **101** and then rotating it to bring ears **103** out of register with notches **102'**, the ears and the flange **104** thereafter holding the disk from vertical displacement but allowing its rotation. The limit of rotation of the disk during operation of the device is such that the ears **103** cannot accidentally move back into register with notches **102'**.

Depending boss **98** is integral with but eccentrically located on disk **99** (Figs. 1, 3 and 8). Integral with and upstanding from disk **99** is an eccentrically arranged lug **105** supporting a cross pin **106** which provides a pivot for regulating handle **107**. The handle is formed as an inverted channel having top wall **108** and side walls **109**, the pivot pin **106** extending through said side walls, the latter taking lug **105** nicely between them.

Handle **107** has at one end a pointer-portion **110** which is pinched down, as viewed in plan (Fig. 2) to be of a width to be taken nicely in regulation-setting notches **79** and yet to leave side walls **109** sufficiently spread to take regulation-setting projections **80**. Thus, the handle may be held against rotation in a number of settings equal to the sum of the number of notches and projections. The top wall of the handle at its other end is provided with a thumb pressure pad **111** beneath which is mounted an expansion spring **112** adapted to bias the handle in a counterclockwise direction, thus tending constantly to engage the pointer **110** with the setting notches or projections. Lug **113**, upstanding from disk **99** and having sliding fit between side walls **109**, takes a part of the load in the transmission of torque from the handle to disk **99**.

Since coil **84** yieldably tends to hold the lower end of rod **85** approximately centered with respect to jacket **68**, and since the upper end of the rod is mounted in disk-socket **98** which, in all its positions of adjustment, is eccentric with relation to the jacket, it will be seen that rod **85** is always inclined with respect to the longitudinal axis of the jacket.

It will be obvious that by depressing the thumb pad end of the handle, pointed end **110** will be cleared from the setting formations **79** and **80**, whereupon torque applied to the handle rotates disk **99** and, due to the eccentric location of hub **98**, bodily translates the upper end of rod **85** from, for instance, the position of Fig. 6 toward that of Fig. 7. Release of pressure from pad **111** allows spring **112** to engage the pointer with the newly registering setting formation, thus latching the disk **99** and rod **85** in their new positions of adjustment.

The formation of that portion of arm **48** which lies within housing **69** will now be described. The arm is there widened, its edges being downwardly turned to provide flanges **114** which fit, with working clearance, between the housing walls **71**. Pivot shaft **49** passes through those flanges. The widened portion **115** of the arm is centrally cut away to form arms **116** and **117** connected at their ends by cross bar **118**, a counterweight **119** being screwed to the latter. Housing ear **75** is positioned beneath counterweight **119** to act as a stop limiting the counterclockwise movement of arm **48**, as viewed in Fig. 1, and thus establishing the height to which snuffer **46** is elevated above the main burner when the latter is in full operation. Weight **119** substantially counterbalances the longer portion of arm **48** and the snuffer annulus **46**, rendering the snuffer substantially non-responsive to vertical acceleration.

Ears **120** and **121** are struck upwardly from arms **116** and **117**, respectively, the ears being substantially in ver-

tical alinement with pivot **49** when arm **48** is exactly horizontal. Ear **120** serves as a stop for arm **48** under a "shut-off" setting of handle **107**, as will later appear, while ear **121** functions as a crank arm in the operative connection between rod **85** and arm **48**.

Secured to rod **85** at a point above arm **48**, is crank arm **122** (Figs. 1 and 6 to 8) whose distal end is connected to crank arm **121** by link or connecting rod **123**. The point of pivotal connection **124** between crank **121** and connecting rod **123** lies substantially in the vertical axial plane of pivot **49** when arm **48** is exactly horizontal. Crank **122** is extended at the opposite side of rod **85** to form a stop lug **125** which, in the shut-off position of adjustment of rod **85** engages lug **120** to positively hold arm **48** and snuffer **47** down.

In considering the showing of Fig. 6, it is to be remembered that, as stated in the brief description of the figure, rod **85** is shown as shifted to a position of regulation other than that it occupies in Fig. 1, for, with rod **85** in the position of Fig. 1, crank **122**, as viewed in plan, is normal to the axis of arm **48**.

Though not essential to the operation of the above described mechanism and therefore not to be considered as limitative on the invention, it is sometimes of advantage to provide means for snapping arm **48** to fully elevated or fully depressed positions as pivot point **124** passes through the vertical axial plane of pivot **49** during actuation of crank **122** by thermostatic rotation of rod **85** under circumstances to be described. We have devised a particularly efficient and simple snap-over mechanism for this purpose, as disclosed particularly in Figs. 1 and 4. A formation adapted to function as a snap-spring anchor, fixed with respect to housing **69**, is illustrated in detached aspect in Fig. 4 and is generally indicated at **126**. This anchor includes arms **127** connected by bridge **128** and from one of which arms there extends a member **129** having an attachment tab **130** extended through housing-top **70** as at **131** (Fig. 3). Arms **127** are notched at **132** to take pivot shaft **49**, said shaft acting to support the anchor. Bridge **128** is pierced at **133** to receive the tab **134** of snap-over, loop-spring **135** which, in Fig. 4, is shown in unstressed condition. The tab **136** at the other end of the spring loop is adapted to be engaged with ear **137** (Fig. 1) punched down from the web portion of channeled arm **48**.

Spring **135** is installed in stressed condition as shown in Fig. 1, functioning resiliently to hold arm **48** either in the full line or dotted line position of that figure. As will later appear, the reaction of coil **84** to changing temperature conditions build up forces which finally become of sufficient magnitude to overcome the opposing force of spring **135**; and the arm **48** with its annulus **46** is snapped from full line position to dotted line position, or vice versa. Shaft **49** is stationary and does not swing with arm **48**; so that the pressure of member **126** against it does not impede the arm action.

Unit A is contained in housing sleeve **60**, the lower edges of walls **71**, where they extend beyond jacket-tube **68**, engaging the upper end of the sleeve. The segmental flanges **72** of housing **69** have down-turned, diametrically opposite lugs **138** which are radially spaced from tube **68** (Fig. 8) and fit nicely within the bore of sleeve **60**, thus serving to annularly space jacket **68** and sleeve **60**. Sleeve-carried screws **139** (Fig. 2) are threaded through lugs **138** to hold the unit A releasably within sleeve **60** and in fixed location with respect to the other units of the heater. For instance, the unit is thus positioned so snuffing annulus **46** is held substantially coaxial with the burner cartridge (not shown, but previously identified). The described coaxial setting of jacket **68** in sleeve **60** establishes between them a vertically extending annular space **140**, the space opening to the atmosphere at its lower end and also at its upper end **141** (Fig. 1). The exterior of thermostat jacket **68** is thus exposed, throughout its length, to the temperature

conditions of the air surrounding the heater, with obvious advantage. It is also to be noted that the upper end of the bore **142** of jacket **68** opens to the atmosphere through the housing shell **69**, so that air can move through the jacket and past the thermostatic element **84**.

It will now be assumed that snap-over spring **135** is omitted from the assembly. Before proceeding to a detailed discussion of the calibration and regulation of the thermostatic element, it is first to be noted that, with the upper end of rod **85** fixed against translation, a rising temperature applied to thermostatic coil **84** causes that coil to uncoil or tend to uncoil, thus rotating or tending to rotate, rod **85** and crank arm **122** in a counterclockwise direction (Fig. 6) thrusting on connecting rod **123** and crank arm **121** in a manner tending to swing arm **48** in a clockwise direction from the full line position of Fig. 1 to the dotted line position to lower the snuffer. On the other hand, a decreasing temperature applied to coil **84** acts reversely, that is, it tends to swing arm **48** in a counterclockwise direction to raise the snuffer.

It will have been predetermined that, with the thermostatic coil **84** in equilibrium, and the upper end of rod **85** held against translation, it requires a rise or fall of a given number of degrees or a fraction of a degree in temperature to rotate rod **85** about its axis sufficiently to swing arm **48** from either the full line or the dotted line position to a midway position. We will call this predetermined extent of rise or fall in temperature the "operating differential."

In order to explain the setting, regulation and operation of the thermostatic control, it will be assumed that unit A is detached from the heater, that snap spring **135** is detached from the assembly, and that certain steps are taken that, actually, are taken only during the initial preparation of a given unit for service, and certain other steps taken that, actually, may be taken only in establishing calibrations which are thereafter reproduced as standard for all thermostatic controls of like structure. It is, of course, to be remembered that the particular procedures described are given by way of example, only, and are not at all to be considered as limitative either on the practices which may actually be put into effect nor on the invention.

It will be assumed that regulator handle **107** is set at a point representing 32° F. on calibrations **77**, it resulting that arm **85** and crank arm **122** are approximately in the positions of Fig. 7 except that they will be further to the left so that definite clearance exists between stop **120** and lug **125**. It will also be assumed that screws **95** are loosened.

The thermostat coil **84** is then exposed to a temperature of 32° F., as by immersing it in a water bath of that temperature. It will have been predetermined that, when the above conditions prevail, the thermostat tab **87** will lie in such relationship to the side walls of jacket-slot **88** that it is susceptible of the following operation. Yoke **91** is bodily rotated to shift tab **87** horizontally and thereby, through coil **84**, to impose torque on rod **85** sufficient to swing crank **122** in a clockwise direction (Fig. 7) through such an angle that, through connecting rod **123** and crank **121**, arm **48** and annulus **46** are moved to a position of equilibrium; that is, midway between the full and dotted line positions of Fig. 1. Screws **95** are then tightened and, as a precaution, solder **143** may be applied to the screw and leg **90** to prevent the thermostat from subsequently getting out of adjustment.

If, now, the water bath be lowered in temperature, coil **84** reacts in a manner to rotate rod **85** clockwise (Fig. 7) swinging crank **122** clockwise and, through link **123**, swinging arm **48** counterclockwise, thus raising annulus **46** to the full line position of Fig. 1. The operating differential necessary to accomplish this movement is very slight, say about 1° F.

Now, assume that, with the regulator still set at 32° F.,

the temperature of the water bath rises above 32° F. by an amount equal to the operating differential. Thermostat coil **84** will respond in a manner to rotate rod **85** in a counterclockwise direction (Fig. 7) thus, through crank arm **122** and connecting rod **123**, rotating arm **48** in a clockwise direction (Fig. 1) and depressing annulus **46** to the "snuffing" position indicated by dotted lines in Fig. 1.

If the temperature of the water bath is allowed to continue to rise, with the setting still at 32° F., arm **48**, having reached its limit of clockwise rotation, acts through crank **121**, link **123** and crank arm **122** to prevent further counterclockwise rotation of rod **85**. Accordingly, the thermostat coil, in its effort to seek its positions of equilibrium for the higher and higher temperatures to which it is being progressively exposed, becomes stressed to correspondingly greater degrees.

The stress thus built up in the thermostatic coil **84** can be controllably relieved by allowing the upper end of rod **85** to move bodily through predetermined extents to the left from the position of Fig. 7, or, in the example now under particular consideration, from its initial position as established by the 32° F. condition of the coil. Accordingly, if we wish to determine and mark any particular position of the regulating means which will correspond with some higher temperature at which we choose to have the snuffer rise to equilibrium position, we may proceed as follows.

The water bath is raised to and held at a selected temperature for which we are to set the regulator. The upper end of rod **85** is then manually moved bodily to the left, thus progressively relieving the built-up stress in the spring coil and thus correspondingly lessening the effective pressure which is tending to hold arm **48** from swinging in a counter-clockwise direction. The left-wise movement of the upper end of the rod is continued until arm **48** and annulus **46** are in equilibrium condition, and the setting of the regulator is marked on scale plate **76**. If this setting be held and the temperature of the thermostatic coil be lowered by an amount equal to the "operating differential" rod **85** will be rotated about its axis in a clockwise direction (Fig. 7) and thus swing arm **48** in a counterclockwise direction sufficiently to carry annulus **46** to the full line position of snuffing of Fig. 1.

From such procedures, or by calculations based on the known response-characteristics of element **84**, scale **77** is arrived at, which, of course, is duplicated on all thermostats having the same characteristics, and may include any appropriate number of individually marked settings between the limits determined upon.

If the snap-over spring **135** be installed after the device has been adjusted and calibrated as above, it will, of course, prevent the arm **48** and annulus **46** from dwelling in equilibrium positions, that is, positions mid-way between the full and dotted line positions of Fig. 1. Since the thermostatic coil **84** must overcome the force of spring **135** in order to actuate the snuffer, the value of the "operating differential" will be slightly increased. On the other hand, the snap-over action has the advantage of preventing the arm **48** from hovering in equilibrium condition and thus from being susceptible to extraneous forces which might otherwise cause undesirable snuffer-movement.

It will be seen that regulation of the thermostatic control may be considered broadly as being accomplished by translation of the upper end of rod **85** while the distal end of crank **122** is restrained from movement in the same direction. In the illustrated case, this translation is in a direction generally parallel to the plane of movement of crank arm **121**, but this is not to be considered as limitative on the invention.

However, it will be seen that it is not necessary that the translation be exactly parallel to the plane of crank-movement, for it suffices if the direction of movement of the upper end of the rod has a sufficiently large component parallel to that plane to give the desired regulation range; and the fact that the direction of movement may have other components does not necessarily interfere with the operation of the device. We have taken advantage of this fact in developing the exceedingly simple and sure regulation means which is here illustrated and the elements of which have been described.

Assuming the device is in the condition of Fig. **6**, if regulating handle **107** be rotated in a clockwise direction, as viewed in Fig. 2, disk **99** is, of course, rotated in the same direction, causing the eccentric boss **98** to follow the arcuate path **144** (Fig. 7) carrying the upper end of rod **85** with it, the link connection **123** holding the distal end of crank **122** against appreciable bodily movement while this is occurring. As is apparent, the direction of movement represented by arc **144** has a sufficiently extensive component of movement parallel to the plane of the direction of movement of crank arm **121**, to permit an appreciable range of regulation. It will be seen that it is unnecessary to provide slideways or close-fitting guiding elements usual to translation-control mechanism, thus avoiding the expense and the installation and operating difficulties of such usual mechanisms.

Crank **122** is, of course, very close to the upper end of the relatively long rod **85**, and the lower end of the rod, where it is supported by coil **84**, may be left free to have the slight bodily movement incident to translation of the upper end of the rod during regulation operations. However, the side arms of stirrup **92** and flanges **93** protect said lower end and prevent accidental excessive bodily displacement thereof.

If pointer **110** be swung to the "off" position on the scale **77** (Fig. 2) the upper end of rod **85** is moved to the position shown in Fig. 7, where lug **125** on crank **122** engages stop lug **120** on arm **48**, holding that arm so snuffer **46** is held depressed in its lowest position. Then, no matter how low the temperature may drop, clockwise rotation of rod **85** and crank **122** is prevented by the engagement of lug **125** with stop **120** and the coil **84** is thus ineffective to elevate the snuffer.

In Figs. 11 through 15, there is shown a variational embodiment wherein the burner unit is in the form of an annulus and the thermostatic control unit is, in effect, nested within the annulus bore. The units differ in certain particularities from those previously described but are, in principle, alike in other regards.

The dome and the bottom wall of tank or reservoir **14*a*** are indicated at **12*a*** and **13*a***, respectively, the dome having a central, downturned neck **25*a*** and the bottom wall having a central upturned neck **160** which has a horizontal shoulder portion **161**. A relatively short housing sleeve **24*a*** is extended through and welded to neck **25*a***, the sleeve projecting somewhat above the top of dome **12*a***. The lower end of an inner housing tube **162**, annularly spaced from tube **24*a***, is welded to bottom-neck **160**, while its upper end is about flush with the top of dome **12*a***.

Adapted to be removably inserted in tank **14*a*** through the annular space between housing tubes, is an annular, cartridge-form burner assembly or unit **23*a***. The cartridge includes inner and outer tubular walls **163** and **164'**, respectively, spaced radially apart to receive between them the main burner wick **29*a***. The top face **164** of the annular body of wicking is substantially flush with the tops of walls **163** and **164'**. Outer wall **164'** is apertured at least in that portion which extends below tube **24*a***, so the wick is exposed to the fuel within tank **14*a***. External flange **165** on cartridge wall **164'** engages the upper end of housing tube **24*a*** to establish the limit to which the cartridge may be thrust into the tank. The lower end of the wicking space is bridged by apertured end wall **166**.

A ring **170** is welded within the upper end of cartridge-wall **163**, being bent inwardly to form a flange **171** fitting within housing tube **162**, and then being bent horizontally to form an internal annular shoulder **172**.

Thrust into the upper end of main wick **29*a*** is pilot burner **173** made up of a tubular wire screen **155*a*** whose

upper end **156a** projects well above main wick **29a**. Screen **155a** is filled with wicking **28a** to a point a short distance above surface **164** of the main wick. The pilot wick is, in effect, a part of the main wick, fuel being supplied to it via the main wick.

The thermostatic control unit B is bodily movable into and out of operative association with the burner assembly. The housing structure whereby this is accomplishable will first be described, without regard to the contained mechanism, it merely being noted at this point that when that housing structure is releasably clamped in assembly with the other heater units, all parts of the burner and control units are releasably held in register with one another in the positions of Fig. 11.

Sleeve **68a** has an external collar **174** at its upper end which fits within the bore of ring-flange **171** and is seated on annular shoulder **172**. Welded to the lower end of sleeve **68a** is an end plate **175** which is apertured at **176**. After the sleeve **68a** is lowered to position, lock-disk **177** is applied across the bore of the lower neck **160**, with the disk-flange **178** in engagement with shoulder **161**, and screws **179** are extended through disk **177** and threaded into end plate **175**. The screws draw sleeve **68a** downwardly to tightly engage collar **174** with shoulder **172**. This action, in turn, draws burner-cartridge flange **165** into tight engagement with the top of tube **24a**, it following that screws **179** act to tightly clamp both the burner unit and the control unit against axial or rotational displacement.

Locking disk **177** is apertured at **179'**, so air surrounding the heater and entering base-chamber **20a** through openings **21a**, may pass through plate openings **176** into the bore **180** of jacket **68a**, within which bore the thermostatic element **84a** is disposed. Element **84a** is a bi-metallic member of the resilient, open coil type, the lower end thereof being fixed at **181** to rod **85a**. Rod **85a** is mounted for rotation in end plate **175** and bridge **182**, cotter key **183** holding the rod against displacement upwardly through jacket **68a**. Bridge **182** is rigidly held in spaced, vertical relation with sleeve **68a** by post straps **184**.

Secured to the upper face of bridge **182** is a bracket arm **185** which supports at its lower end a scale-plate **186**, carrying an arcuate flange **187** centered on rod **85a** and provided with notches **188**. The scale-plate preferably rests on dome **12a** when unit B is assembled with the heater, and the notches are scaled with temperature indicia, as at **189**.

Applied to the upper end of rod **85a** and adjustably fixed against rotation with respect thereto at **217**, is a regulating handle **107a** which has sufficient vertical resilience to tend to press its neck **190** into any notch **188** with which it may register. On the other hand, extension **190** may be sprung upwardly to clear the neck from a given notch, and the handle **107a** then swung horizontally to rotate rod **85a** to a position where the neck will register with some other selected notch. Of course, when the neck rests in any one of the notches, the rod **85a** and the lower end of coil **84a** are held against rotation.

The upper end of coil **84a** is secured at **192** to anchor ring **193** which is operatively associated with the torque-transmitting unit indicated at **194**, rod **85a** being taken, with clearance, in the bore **195** of the ring (Fig. 15). The torque-transmitting unit also includes rods **196** which are extended, with slidable clearance, through the diametrically opposite holes **197** provided in ring **193**. Rods **196** extend through and are welded to vertically spaced disks **198**. The disks are centrally apertured at **199** to take rod **85a** with working clearance, and they serve not only as rod-connectors, but also as radiation shields. The upper ends of rods **196** are bent outwardly to form torque arms **200**, said arms extending oppositely and radially with respect to rod **85a**.

It will be seen that torque-transmitting unit **194**, and rod **85a** are relatively angularly and axially movable; that unit **194** and ring **193** (and the attached coil **84a**) are relatively vertically movable; but that unit **194** is fixed against rotation with respect to ring **193**. Consequently, torque applied to ring **193** by rotation of rod **85a** or by the reaction of bi-metallic coil **84a** to temperature changes, tends to rotate unit **194** about the axis of rod **85a** and thus carry torque arms **200** bodily through circumferential paths. The axial expansion and contraction of coil **84a** does not interefer with this movement, due to the capacity for relative vertical movement between ring **193** and rods **196**.

The snuffer or extinguisher (also functioning at times as a re-lighter) is generally indicated at **201** and, in effect, is a split annulus made up of two semi-circulr segments **202** and **203**, the annulus being of such dimensions that, when in assembly with the thermostatic control and the burner unit, it fits over the upper end of main wick **29a** except at **204** where the opposed edges of segments or leaves **202**, **203** are cut away to provide a slot for the reception of pilot **173**. The annulus **201** has external and internal flanges **204'** and **205** which incline downwardly and oppositely outwardly, giving each segment cupshaped, transverse cross section. Flanges **204'** and **205** are adapted to engage the upper ends of cartridge walls **163** and **164'** when the main burner is "off."

The individual fabrication, mounting and operation of the segments **202** and **203** are the same, and therefore the detailed description may be limited to but one of them, though corresponding parts of the two segments are given the same reference numerals so the description will commonly apply. Welded to each snuffer is a flat arm **206** which, in effect, projects into the annulus bore at one side of rod **85a**. The arm is mounted for pivotal movement at **207** about a horizontal axis represented by pivot pin **208** which is in a vertical axial plane of pilot **173** and lies just over the opposed ends of annulus segments **202** and **203** at the side opposite the pilot. Pin **208**, in turn, is supported in bridge-posts **184**, being held against axial dislodgement by having one of its ends **209** turned down into arm-socket **210** (Fig. 11). The distal end **211** of arm **206** is provided, at its under side, with a counter-balance **212**.

At the opposite side of rod **85a**, segment **203** carries a short arm **213**, parallel to arm **206**, which is pivotally connected at **214** to the pin **208** lying at said opposite side of the rod. Depending from each arm **206** is a crank ear **215** which is apertured to take the arm **200** of one of the torque rods **196**. When the annulus **201** is in the "off" position of Fig. 11 (corresponding to the full-line position of Fig. 14) the point of pivotal connection **216** between a given ear **215** and its associated rod-arm **200** lies in vertical alignment with the associated pivot pin **208**.

It will be seen that if torque assembly **194** be rotated in a counterclockwise direction, from the aspect of Fig. 13, the crank ear **215** associated with segments **203** will be swung in a clockwise direction, as viewed in Fig. 14, thus swinging the segment, itself, towards. to, or beyond the dotted line position of Fig. 14, thus exposing one half of the upper end of main wick **29a** so it may automatically be ignited from pilot **173**. The same movement of the torque assembly **194** causes coincident and equal counterclockwise rotation of segment **202**, thus simultaneously exposing the other half of the main wick **29a** to the pilot flame. The previously described capacity for relative vertical movement between rods **196** and torque ring **193**, permits the vertical displacement of rods **196** due to the vertical component of the swinging movement of crank ears **215**.

With thermostatic coil 84a in eqilibrium, all parts of the assembly are in the full line positions of Figs. 11 to 15. If, now, coil **84a** is exposed to a rising temperature, its reaction imposes a torque on ring **193** and assembly **194** tending to swing crank ears **215** in directions which more tightly seat the snuffer segments on the upper end

of cartridge **23a**. On the other hand, if the coil is exposed to a lowering temperature, its reaction through the torque mechanism tends to swing the segments **202, 203** in directions uncovering the main wick **29a** and thus allowing it to be automatically lighted from the constantly burning pilot.

It will be obvious that, with the upper end of coil **84a** held against rotation, rotation of rod **85a** by handle **107a** imposes on coil **84a** a regulatory stress. Scale **189** is so calibrated that any given setting of the regulating handle with respect to that scale, establishes a pre-stressing of the coil such, that when the coil is subsequently exposed to the indicated temperature, said coil will be substantially in equilibrium and therefore all elements will be in the positions of Fig. 11. If the temperature drops below the indicated temperature, the coil, in seeking to reach its position of equilibrium for the new temperature, acts through torque assembly **194** to elevate the snuffer segments and thus cause the automatic lighting of the main burner. Then, as the temperature rises and finally reaches the indicated degree, the coil **84a** is restored to its original condition of equilibrium and the snuffer **201** is returned to the position of Fig. 11, thus snuffing the main burner flame, but not, of course, interfering with the pilot flame.

While we have shown and described preferred embodiments of our invention, various changes in design, structure and arrangement may be made without departing from the spirit and scope of the appended claims.

We claim:

1. A thermostatic control unit comprising a tubular housing, a bi-metallic coil member axially centered within and held against bodily movement with respect to the housing, a rotatable rod member within the housing and fixed to one end of the coil member, a control element mounted, independently of the rod, on the housing for pivotal movement about an axis which is transverse with respect to the rod axis, a crank on the control element, a positive push-pull connection between one of said members and said crank, all in a manner whereby temperature-responsive movement of the coil actuates said crank to move the control element pivotally in one direction or the other; manually operated means applied to the rod for moving it in a manner regulating the effective stress in the coil member, and latch means releasably holding said manually operated means in selected positions of adjustment.

2. A thermostatic control unit comprising a housing, a bi-metallic coil, means fixing one end of the coil against movement with respect to the housing, a rod secured at one point to and supported by the other end of the coil, means on the housing rotatably supporting said rod at a point axially spaced from said one point, a control member movably supported on the housing, and an operative connection between the rod and control member whereby temperature-responsive movement of the coil moves the control member; said means for rotatably supporting the rod comprising a member rotatably supported by the housing for rotation about an axis substantially in line with the axis of the coil, said rod engaging the supporting member at a point eccentric with relation to the axis of rotation of said supporting member.

3. A thermostatic control unit comprising a housing, a bi-metallic coil, means fixing one end of the coil against movement with respect to the housing, a rod secured at one point to and supported by the other end of the coil, means on the housing rotatably supporting said rod at a point axially spaced from said one point, a control member pivotally supported on said housing, a crank on said rod, a crank on said control member, and a link connection between the cranks; said means for rotatably supporting the rod being shiftable in a direction having an appreciable component parallel to the plane of movement of the second mentioned crank, and means for so shifting said last named means.

4. A thermostatic control unit comprising a housing, a bi-metallic coil, means fixing one end of the coil against movement with respect to the housing, a rod secured at one point to and supported by the other end of the coil, means on the housing rotatably supporting said rod at a point axially spaced from said one point, a control member pivotally supported on said housing, a crank on said rod, a crank on said control member, a link connection between the cranks, and means for translating the said rod, at its housing-supported point, in a given direction while the distal end of the rod crank is restrained against movement in that direction.

5. A thermostatic control unit comprising a housing, a bi-metallic coil, means fixing one end of the coil against movement with respect to the housing, a rod secured at one point to and supported by the other end of the coil, means on the housing rotatably supporting said rod at a point axially spaced from said one point, a control member pivotally supported on said housing, a crank on said rod and located between said points, a crank on said control member, a link connection between the cranks, and means for translating the said rod, at its housing-supported point, in a given direction while the distal end of the rod crank is restrained against movement in that direction.

6. A thermostatic control unit comprising a housing, a bi-metallic coil, means fixing one end of the coil against movement with respect to the housing, a rod secured at one point to and supported by the other end of the coil, means on the housing rotatably supporting said rod at a point axially spaced from said one point, a control member pivotally supported on said housing, a crank on said rod, a crank on said control member, a link connection between the cranks, means for translating said rod, at its housing-supported point, in a given direction while the distal end of the rod crank is restrained against movement in that direction, and means for releasably holding said rod, at its housing-supported point, in selected positions of translation.

7. A thermostatic control unit comprising a housing, a bi-metallic coil, means fixing one end of the coil against movement with respect to the housing, a rod secured at one point to and supported by the other end of the coil, means on the housing rotatably supporting said rod at a point axially spaced from said one point, a control member pivotally supported on said housing, a crank on said rod, a crank on said control member, and a link connection between the cranks; and means on said rod and member adapted to coact, when the rod is rotated to a given position, in a manner whereby the member is held against pivotal movement in one direction, at least.

8. A thermostatic control unit comprising a housing, a bi-metallic coil, means fixing one end of the coil against movement with respect to the housing, a rod secured at one point to and supported by the other end of the coil, means on the housing rotatably supporting said rod at a point axially spaced from said one point, a control member pivotally supported on said housing, a crank on said rod, a crank on said control member, and a link connection between the cranks, a lug on the first mentioned crank and a lug on said member, said lugs being adapted to coact, when the rod is rotated to a given position, in a manner whereby the member is held against pivotal movement in one direction, at least.

9. In a thermostatic control unit, a housing, a bi-metallic coil, means fixing one end of the coil against movement with respect to the housing, a rod secured at one point to and supported by the other end of the coil, means on the housing rotatably supporting said rod at a point axially spaced from said one point, said last named means being movable transversely with respect to the axis of the housing, and means for so moving said last named means and thereby translating the rod, at its housing supported point, with relation to the housing-fixed end of the coil.

10. The combination of claim 9; wherein the means rotatably supporting the rod embodies a member rotatably mounted on the housing, and a rod-taking element on said member, said element being located eccentrically with relation to the axis of rotation of said member.

11. A thermostatic control unit comprising a housing, a bi-metallic coil within the housing, a rod rotatably mounted in the housing and extending axially through the bore of the coil and fixed at one end to said coil, adjustable means for holding the rod in a selected one of a plurality of positions against rotation with respect to the housing, a control member pivotally connected to the housing, a crank arm on said control member, a torque-transmitting assembly applied to the other end of the coil, and a positive push-pull connection between the torque transmitting assembly and said crank arm whereby rotation of said assembly under temperature-responsive movement of the coil actuates said crank arm to move the control member pivotally in one direction or the other; said torque transmitting assembly including a member extending substantially axially parallel to the rod, said last named member and said coil being relatively

axially movable but held against relative rotation, and a crank arm on said last named member and operatively connected to the first mentioned crank arm.

12. A unit as in claim 11, wherein the respective planes of rotation of said crank arms are normal with respect to each other.

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THERMOSTATIC CONTROL UNIT

Original Filed Nov. 7, 1949 3 Sheets-Sheet 1

Fig. 1.

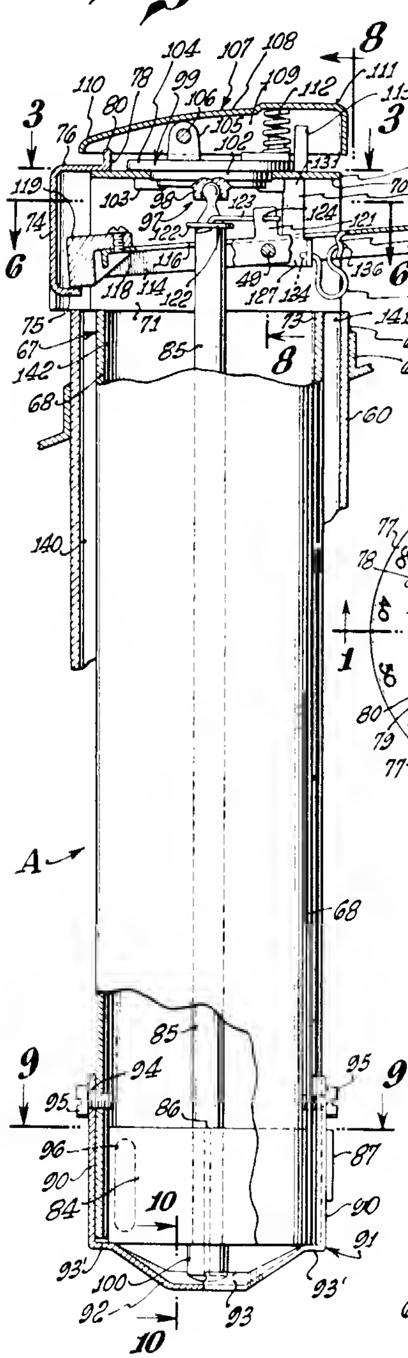


Fig. 3.

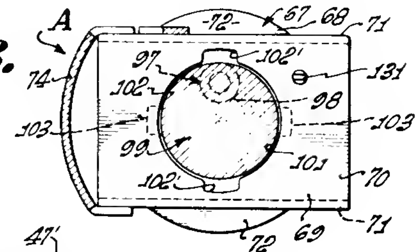
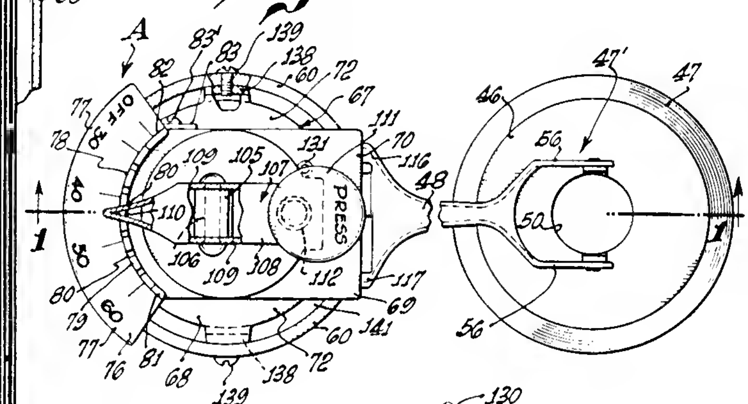


Fig. 2.



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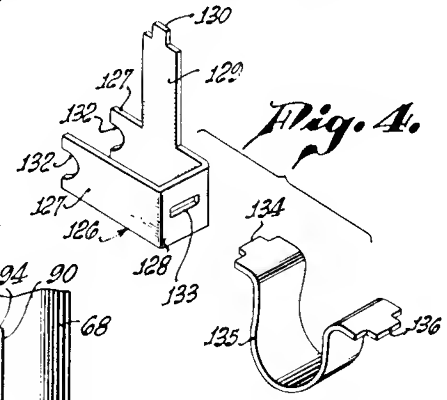
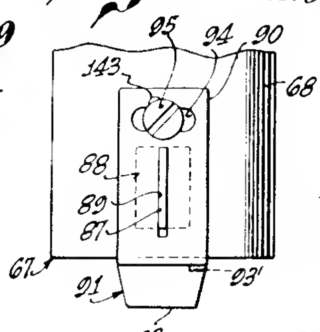


Fig. 5.



ALLEN M. STELLE,
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INVENTORS.

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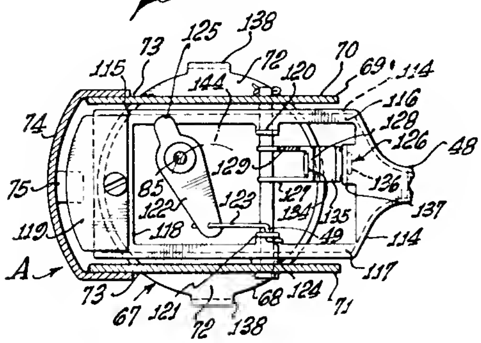
Barkelew & Scantlebury

ATTORNEYS.

Fig. 6.



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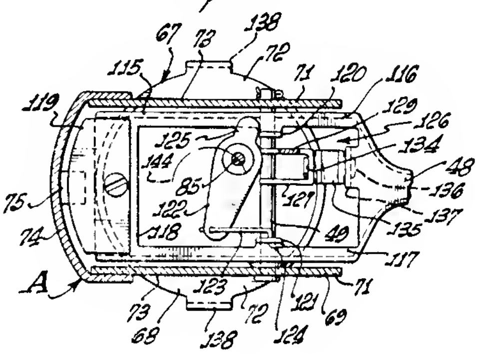


Fig. 8.

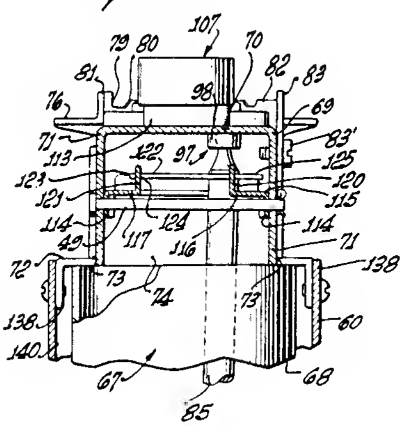
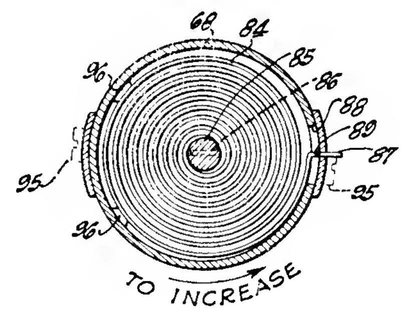


Fig. 9.



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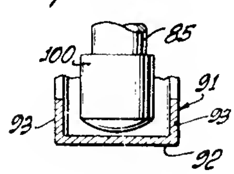

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THERMOSTATIC CONTROL UNIT

Original Filed Nov. 7, 1949 3 Sheets-Sheet 3

Fig. 12.

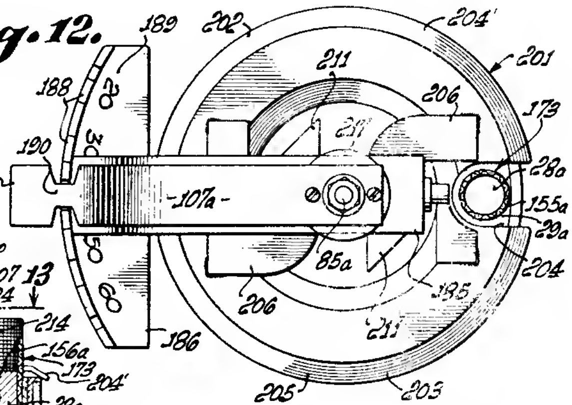


Fig. 11.

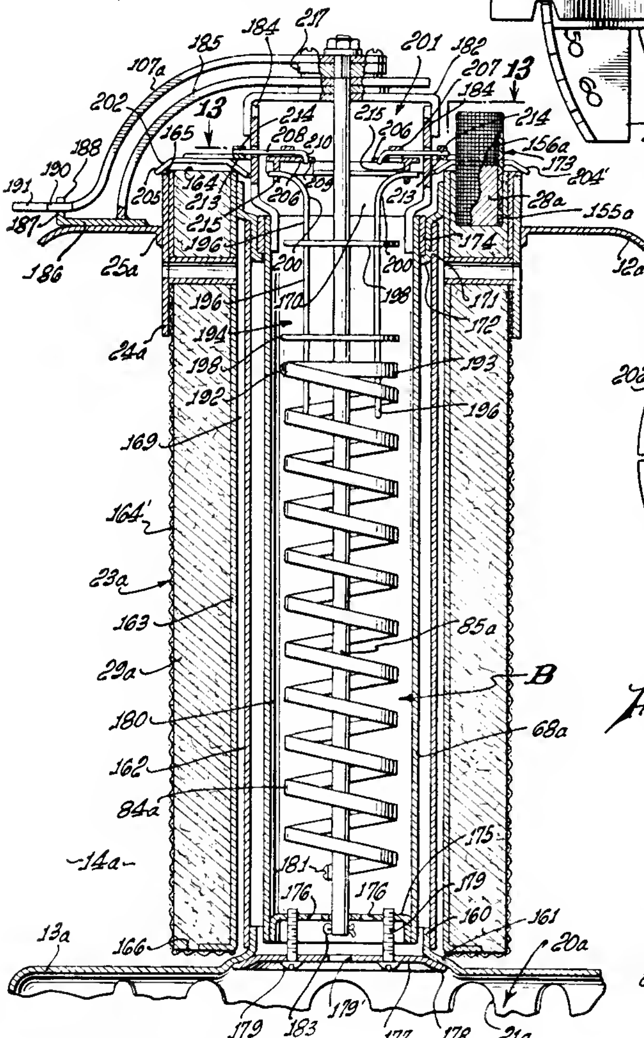


Fig. 13.

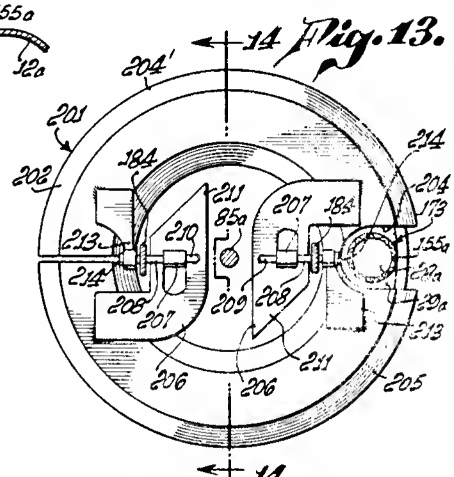


Fig. 15.

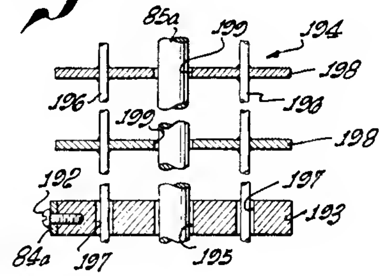
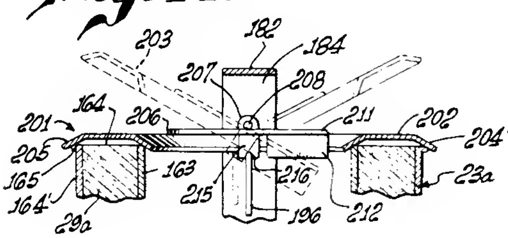


Fig. 14.



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ATTORNEYS.

APPENDIX E

PRECO REPORT RG2:
AUTOMATIC HEATER TESTS, EXPERIMENTAL MODEL GB1

Report No. RG2

AUTOMATIC HEATER TESTS

EXPERIMENTAL MODEL GB1

Written April, 1947

Written By ____
Approved H O Fuchs
Approved ____

Typed:mr
1-11-49

TABLE OF CONTENTS

BACKGROUND

The Interstate Commerce Commission has prepared a ruling requiring that refrigerator cars loaded in the Northwest with apples or pears shall be equipped, during the winter months, with a heating device which may be lighted or extinguished as the inside car temperatures require. Because of this ruling, much research has been conducted by several companies to develop a heater with an intergral thermostatic control. The general trend has been to use a liquid fuel to obtain maximum safety and simplicity of design. Methanol has found general acceptance largely because it is relatively odorless, does not produce soot easily, and has a rather high flash point (60°F. closed cup).

OBJECT

The object of this investigation was to determine a simple practical configuration for a wick and snuffer combination that would be adaptable to a thermostatically controlled unit delivering between 5000 and 6000 B.T.U. per hour (.52 - .62 lbs. Methanol per hour). See design specification GDS1 for other design limitations of size, shape, etc.

CONCLUSIONS

A very promising configuration was developed comprising a solid wick, a pilot flame holder screen, and a snuffing plate.

RECOMMENDATION

Further investigations should be made into more detailed characteristics of this configuration. Specifically, determination of the following will be of immediate value:

1. The relationship of wick diameter to burning rate.
2. The relationship of the relative tightness of packing the wicking in the jacket to burning rate.
3. Determine how critical the snuffer height is to burning rate.

All tests should be run for a 24 hour period, or longer.

PARTS TESTED

1. Model EA2 Heater (Drawing X6M1052).

2. Sears Roebuck Automobile Heater.

3. Preco Experimental Heater (Drawing X6M1003) modified for solid wick per Figure 9.

4. Model GB1 Heater Mockup (Drawing X5G22).

5. Wick samples (four types).

    (a) Annular wick with central air draft.

    (b) Solid wick, cotton with glass cap.

    (c) Solid wick, cotton with glass top.

    (d) Solid wick, all glass fiber.

PROCEDURE

The burning tests for the heaters were conducted during September, 1946, near the northwest door in the Shipping Department. The natural draft in this area may have influenced the burning rates upward.

A piece of Lucite was fitted to the heater door opening to permit visual observation of the flame characteristics without creating the added draft of an open door.

Fuel consumption was determined by weighing the heater assembly at irregular intervals during the burning period. The loss of weight is assumed to be equal to the weight of fuel burned. B.T.U. calculations are based on the higher heating value of the fuel (9550 BTU/lb.), since the combustion gasses are exhausted into an air temperature below 60°F. in the closed cargo space.

The wick samples were tested in the Preco laboratory. Each sample was inserted into a short length of steel tubing. This assembly was in turn placed into a beaker of methanol on the laboratory balance. To insure a stabilized burning rate, the wick was lighted and allowed to burn five minutes before readings were taken. The time intervals were measured with a General Electric 120 minute Interval Timer.

As a natural starting point, the Model EA2 manually controlled heater was first investigated to determine its heat output and general characteristics when equipped with its standard snuffer. Once accomplished, three other types of snuffers were investigated for their burning characteristics only.

Testing and analysing the Sears Automobile heater followed.

The experimental heater was then modified to take a solid wick. Three types of wicks and two types of snuffers were tested for flame characteristics and fuel consumption. The three types of wicks were retested in the laboratory to confirm the results obtained in the heater. A preliminary design was drawn. A mockup heater was built to these specifications except the bottom of the fuel tank was left off. A one gallon paint can was substituted for the fuel tank in order that a more rapid fall from full to empty could be had. This resulted in a savings of scarce fuel and time. The mockup was tested for heat output and flame characteristics.

DISCUSSIONS AND RESULTS

It is fundamental that a thermostatically controlled heater must have a means of automatically relighting the main burner. This relighting in a car heater must be done at temperatures as low as 30°F. It is perhaps most easily accomplished by the use of pilot flame. But, since the flash point of Methanol is 60°F., contact between the pilot flame and main wick is essential. With this fact in mind, it is apparent that it would be most economical to make a section of the main wick act as a pilot wick by designing the snuffer so that it would act, essentially, as a wick area reducer.

The EA2 manual heater was tested and found to produce 4700 B.T.U. per hour (.49 #/hr.) when equipped with the manual snuffer (Drawing X1M1038) with which it was originally supplied. This snuffer, of course, has no provisions for a pilot flame.

To provide a pilot, such as is outlined above, two modifications were indorporated in the snuffer (see Figure 1). First, eight equally spaced saw slots were cut in the corner perphery of the snuffer hood. A flame could not be maintained at these slots when the snuffer was down for more than 1/2 hour. Second, four equally spaced 1/4 holes were drilled, in addition to the saw slots, in the top of the hood. Flame could not be maintained at these holes for more than 2 hours. It was also found that upon positioning the snuffer with the edge 1/16" above the wick, large quantities of Formaldehyde were generated. This was determined by the odor and the knowledge that Formaldehyde is made commercially by passing air and methanol vapors over hot copper.

The snuffers shown in Figure 2 and 3 gave much the same results with the added disadvantage that after being left in the pilot position for several minutes, a flash back or minor explosion occurred in the central air tube. This, besides being considered dangerous, usually blew the pilot flame out. No fuel consumption records were made of the above configurations because they were unsatisfactory designs.

The Sears Roebuck heater was examined and burned, Consumption was .19 #/hr. which is good considering the wick is only 3/4" diameter. However, some alcohol vapor was being burned since part of the draft for combustion was being drawn from inside the fuel tank.

To determine if this configuration was as good as it appeared, a replica was made using a 2-1/4" diameter solid wick (Figure 6) and installed in the experimental heater. The replica was simplified in some respects; the lower draft came from outside the fuel tank and the top deflection plate was eliminated. This setup proved to be a dismal failure, burning about .3 #/hr. Because of its poor burning and the fact that it would be quite difficult to adapt an automatic snuffer, the idea was abandoned.

An analysis at this stage of the investigation revealed that a solid wick probably would yield better results than a annular wick since it would (1) reduce the tendency to produce Formaldehyde, (2) eliminate any possible danger of flash back, and (3) be easily adapted to a wick area reducing device for pilot operation by partial snuffing.

Reasoning further, the area reducing device might be allowed to become quite hot and radiate heat back to the surface of the wick to evaporate the methanol more rapidly. This would allow the use of a smaller wick.

The experimental heater was modified with a $2\frac{1}{4}$" diameter wick sleeve (Figure 9). Upon burning, the draft caused the flame to concentrate through the center hole in the snuffer. In order to broaden the flame, and heat the snuffer to higher temperatures, a 20 mesh wire screen was placed around the outer edge of the wick.

This produced a satisfactory flame for full burning. However, on lowering the plate to the top of the wick for pilot operation, the pilot flame burned feebly and was easily blown out.

It had been noticed, in the past, that the flame seemed to cling to hot metalic surfaces. This phenomenon, it was felt, could be applied by inserting a 1/4"diameter copper rod into the center of the wick leaving 3/8" extending out into the pilot flame. As a secondary result, it was expected that the hot rod would evaporate more alcohol to sustain the pilot flame. This configuration was not entirely satisfactory because the pilot flame could not heat the rod to a sufficiently high temperature to maintain flame stability. A 16 mesh, stainless steel screen was rolled to a 1/2" diameter tube, filled to within 7/8" of the end with wicking, and substituted for the rod. The unfilled end extended out 7/8" from the top of the main wick, bringing the two wicks even. This configuration (Figure 7) provided a very stable pilot flame.

It became necessary to find a suitable wicking material, one which would raise alcohol about 8 inches and would not char if the fuel became exhausted. Asbestos cloth had been used previously for wicks in both P.F.E. and Preco heaters, but had not proven altogether satisfactory, since, it was reported, it swelled after long contact with Methanol to the point of restricting the flow of fuel. Glass cloth seemed to present the necessary properties and, therefore, some glass-cotton combination and all glass wicks were made up. Details of this construction are shown in Figure 5. The cotton wicking was Socony 8" Flat Stove Code 667, obtained from Socony Vacum Oil Co., New York. The glass tape was .020" thick, ESS electrical tape, and the all glass fiber was surplus aircraft pipe insulation and can be had from Tubular Weaving Co., Columbus, Ohio as BW-1000-5S wicking.

Further tests were run to determine which had the highest delivery rate (Curve II). During the third test, that on the all glass wick, it was found that the straightening screen around the wick hindered the burning rate and it was removed. Tests on the other two wicks were not repeated with the new condition because of the lack of time. However, tests were conducted in the laboratory on the wicks mounted in beakers (Figure 8). These and the previous tests showed that the all glass wick had a slightly higher delivery rate (Curve III). Also, that the single fold of glass tape provided very little protection against charring of the cotton wick.

Tests conducted on the heater mockup (X5G22) were at first disappointing, the burning rate being about .4 lbs/hr. It was suggested that removing the rain cap would eliminate the trouble. This was tried (Curve IV) and shown to make little difference. The wick size was increased to 2-5/8" in diameter which raised the consumption to the required level. The effect of the rain cap on combustion rate was checked with the larger wick also (Curve IV). It was again found to have no appreciable effect.

The position of the snuffer relative to the wick surface was investigated (Curve V). It was found that approximately 7/8" above the wick was the best position to develop the greatest heat output.

From the data accumulated, the design of Model GB1 (X6G103) was made. The principal differences between the mockup and X6G103 were:

1. Decreased air intake area.
2. Added an air baffle.
3. Increased diameter of chimney from 6" to 7".
4. Placed wick in perforated can.
5. Increased number of sections in wick from 4 to 5.

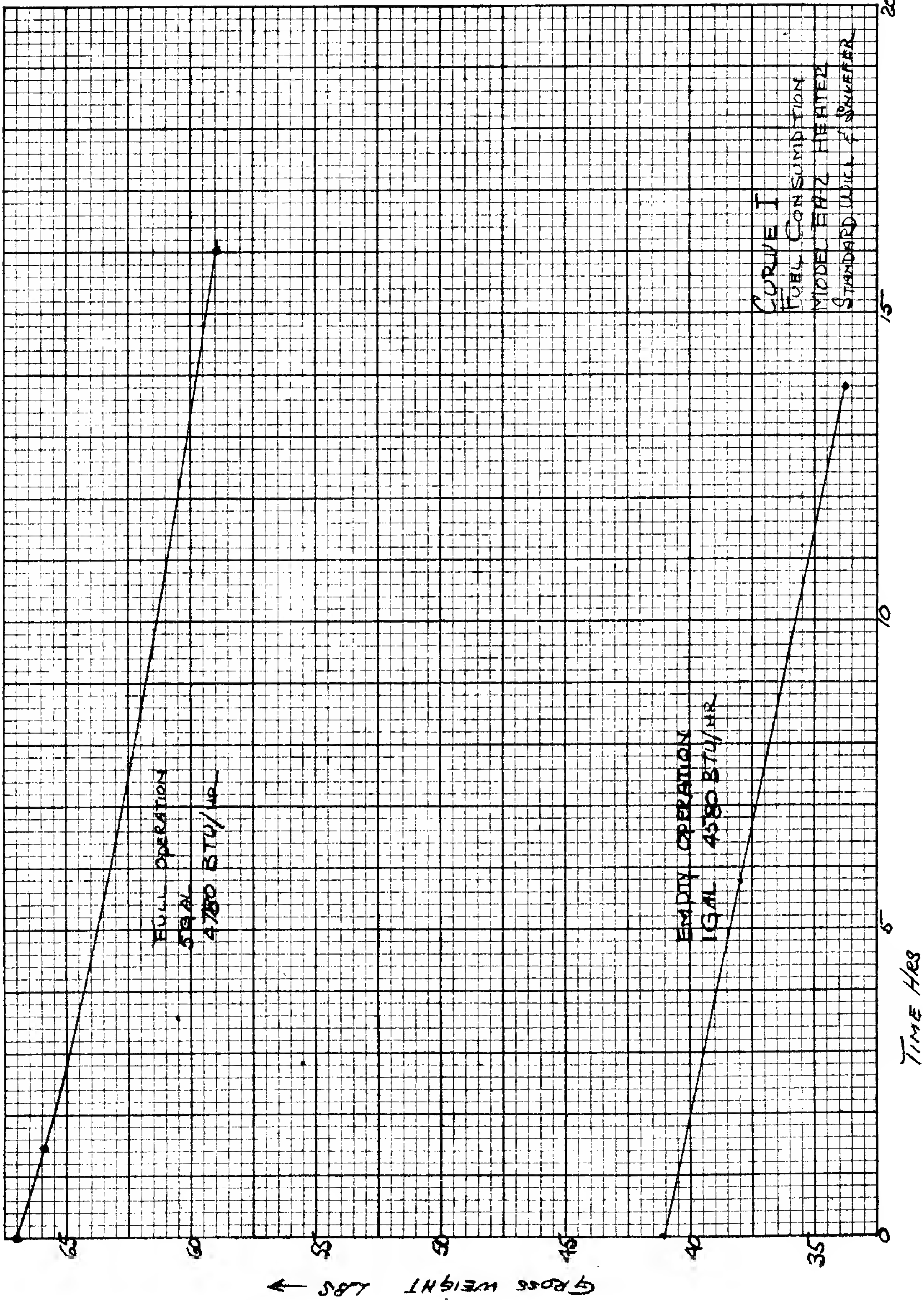
Several heaters were made to this design and loaned to the A.A.R. and U.S.D.A. for inclusion in their transportation tests during December and January of 1946-47.

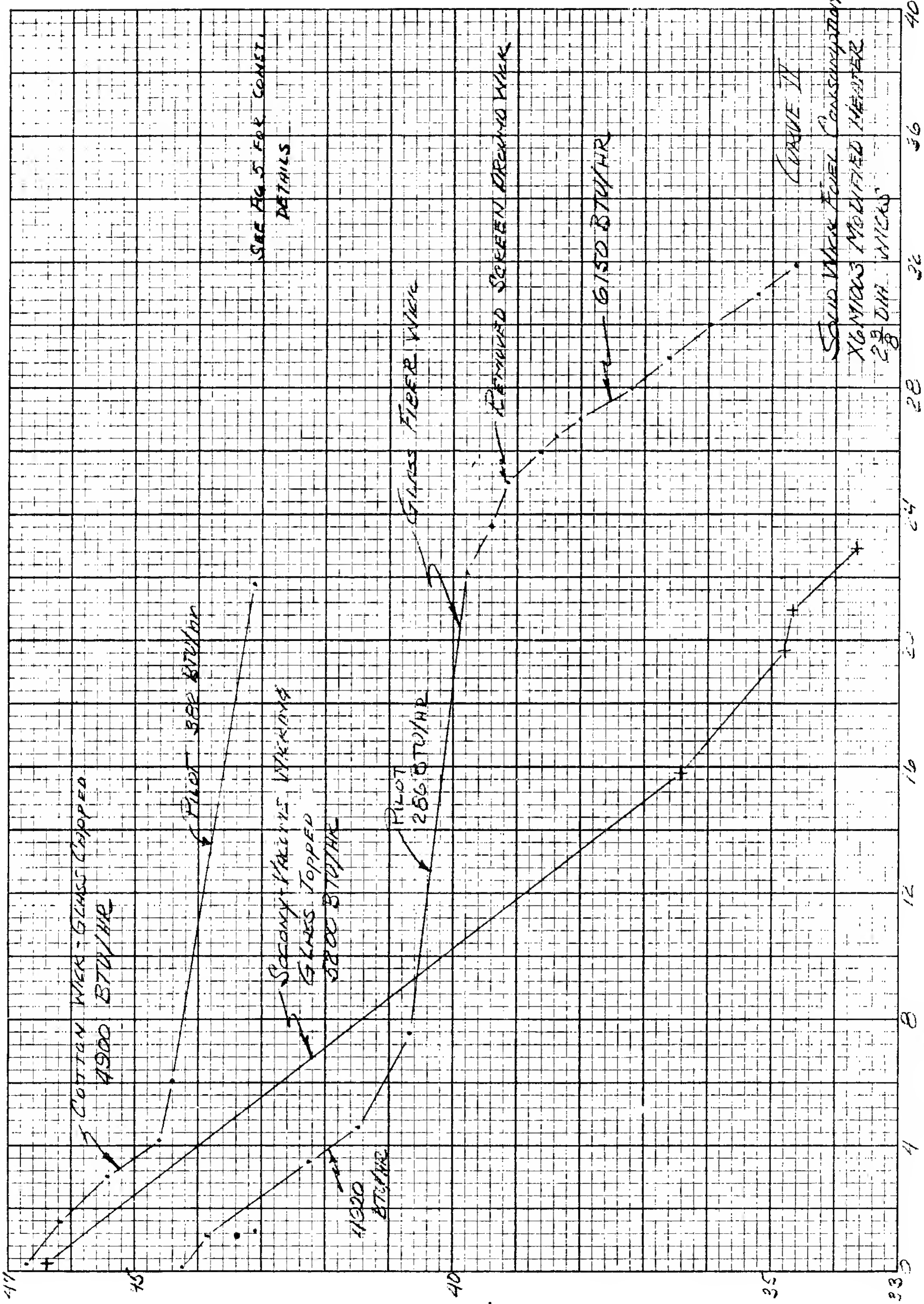
While these heaters were on standing tests, the tank beame hot and resulted in the alcohol vapors building up pressure inside the tank which forced alcohol up and out of the wick sleeve (see trip report to Wenatchee, December, 1946). This condition was corrected by:

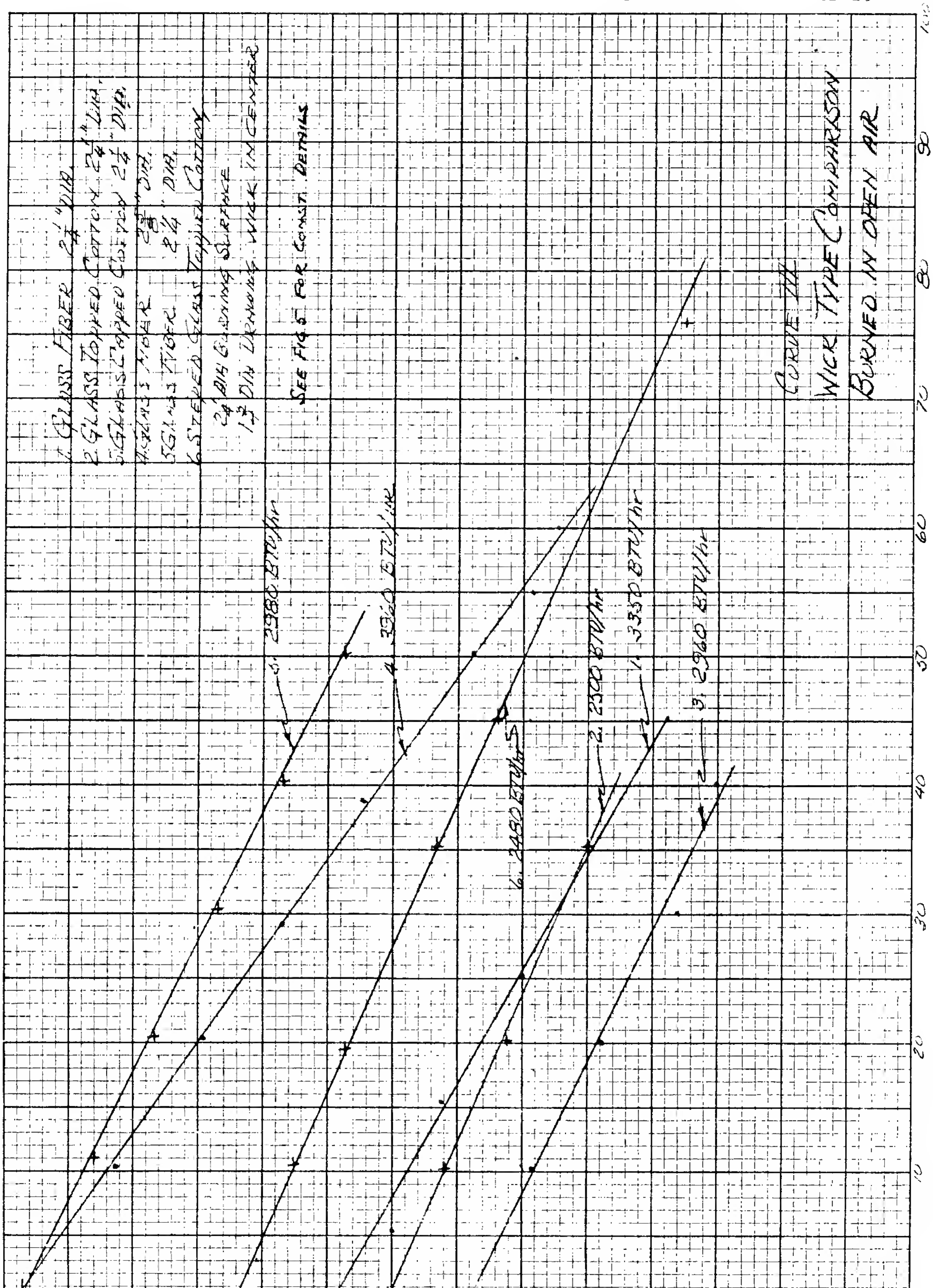
1. Substituting support legs for the chimney sockets to reduce conduction from the hot chimney and to increase air circulation for cooling.

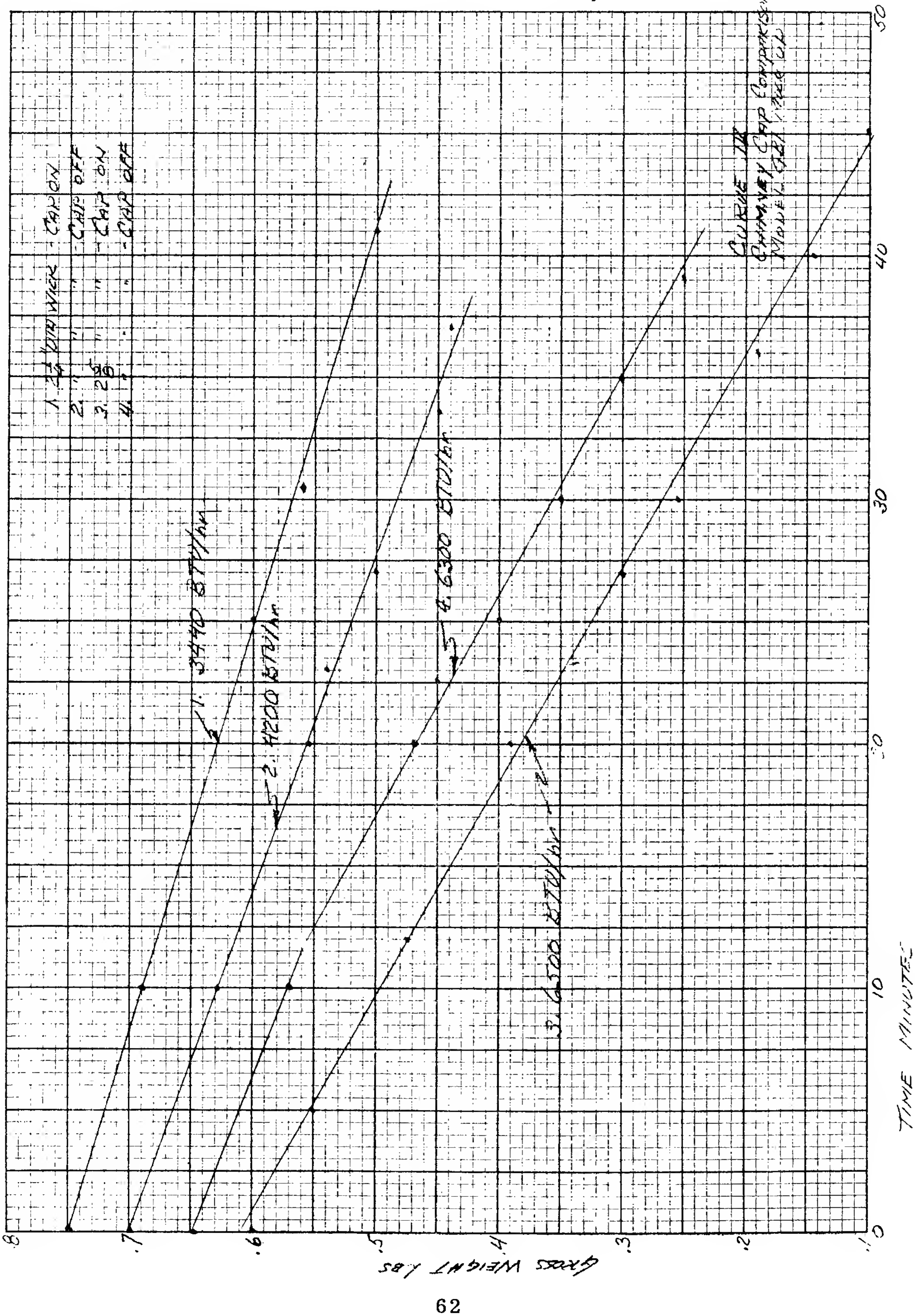
2. Venting the wick sleeve to the inside of the tank for pressure equalization.

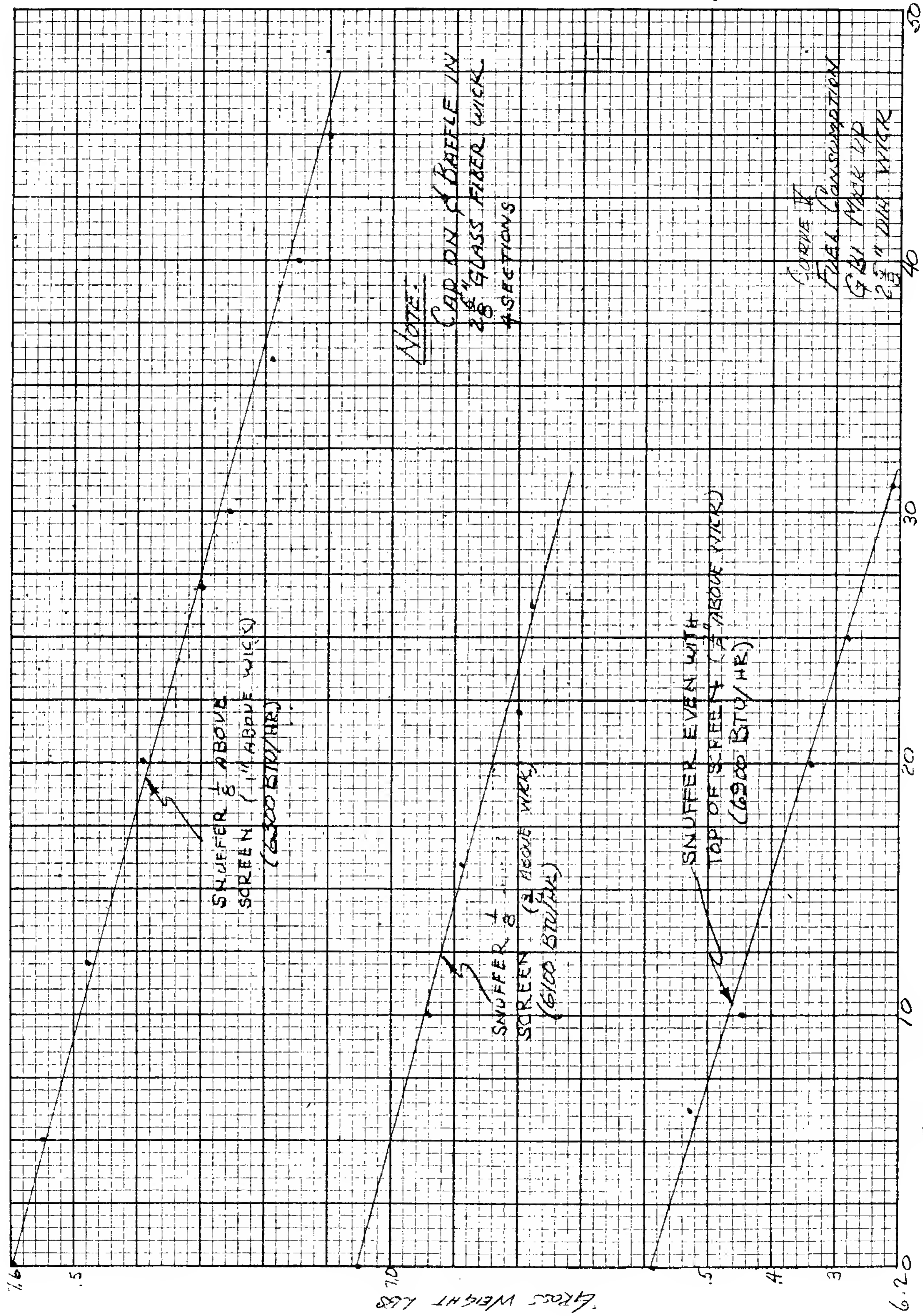
This modified heater was returned to the A.A.R. and U.S.D.A. for their second series of tests (Nos. 14 and 15) in January, 1947. The heater gave a very satisfactory performance, details of which can be found in the U.S.D.A. and A.A.R. comprehensive reports Nos. 12, 13, 14 & 15 of these tests.

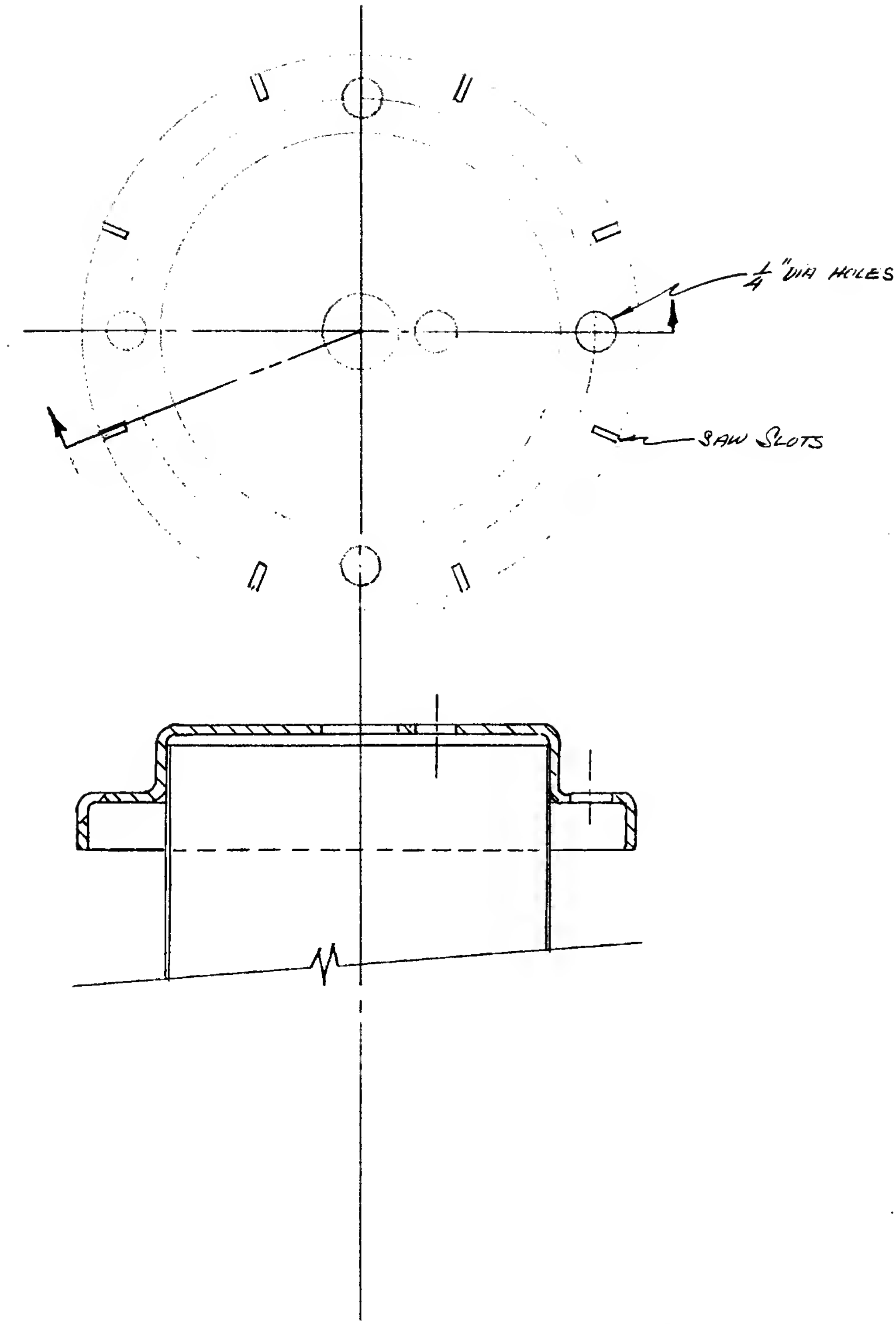

CURVE I
FUEL CONSUMPTION
MODEL EH2 HEATER
FULL OPERATION
EMPTY OPERATION
1 GAL
4580 BTU/HR
TIME HRS
GROSS WEIGHT LBS
0
5
10
15
20
65
60
55
50
45
40
35


CURVE II
SOLID WICK FUEL CONSUMPTION
XG MIC'S MODIFIED HEATER
2 3/8 DIA. WICKS
SEE FIG 5 FOR CONST.
DETAILS
REMOVED SCREEN DRAWING WICK
6150 BTU/HR
GLASS FIBER WICK
PILOT 380 BTU/hr
SOCONY-VACUUM WICKING
GLASS TOPPED
3200 BTU/HR
PILOT
286 BTU/HR
COTTON WICK - GLASS CAPPED
4900 BTU/HR
4320
BTU/HR
TIME HRS
GROSS WEIGHT LBS.
0
4
8
12
16
20
24
28
32
36
40
33
35
40
45
47


1. Glass Fiber 2¼" Dia.
2. Glass Topped Cotton 2¼" Dia.
3. Glass Capped Cotton 2¼" Dia.
4. Glass Fiber Dia.
5. Glass Fiber Dia.
6. Stepped Glass Topped Cotton
2¼ Dia Burning Surface
1¼ Dia Drawing Wick in Center
See Fig. 5 for Const. Details
Curve III
Wick Type Comparison
Burned in Open Air
5. 2980 BTU/hr
4. 3320 BTU/hr
6. 2450 BTU/hr
2. 2300 BTU/hr
1. 3350 BTU/hr
3. 2960 BTU/hr
Time - Minutes
Net Weight - Lbs
0 10 20 30 40 50 60 70 80 90 100
.7 .6 .5 .4 .3 .2 .1 0.00

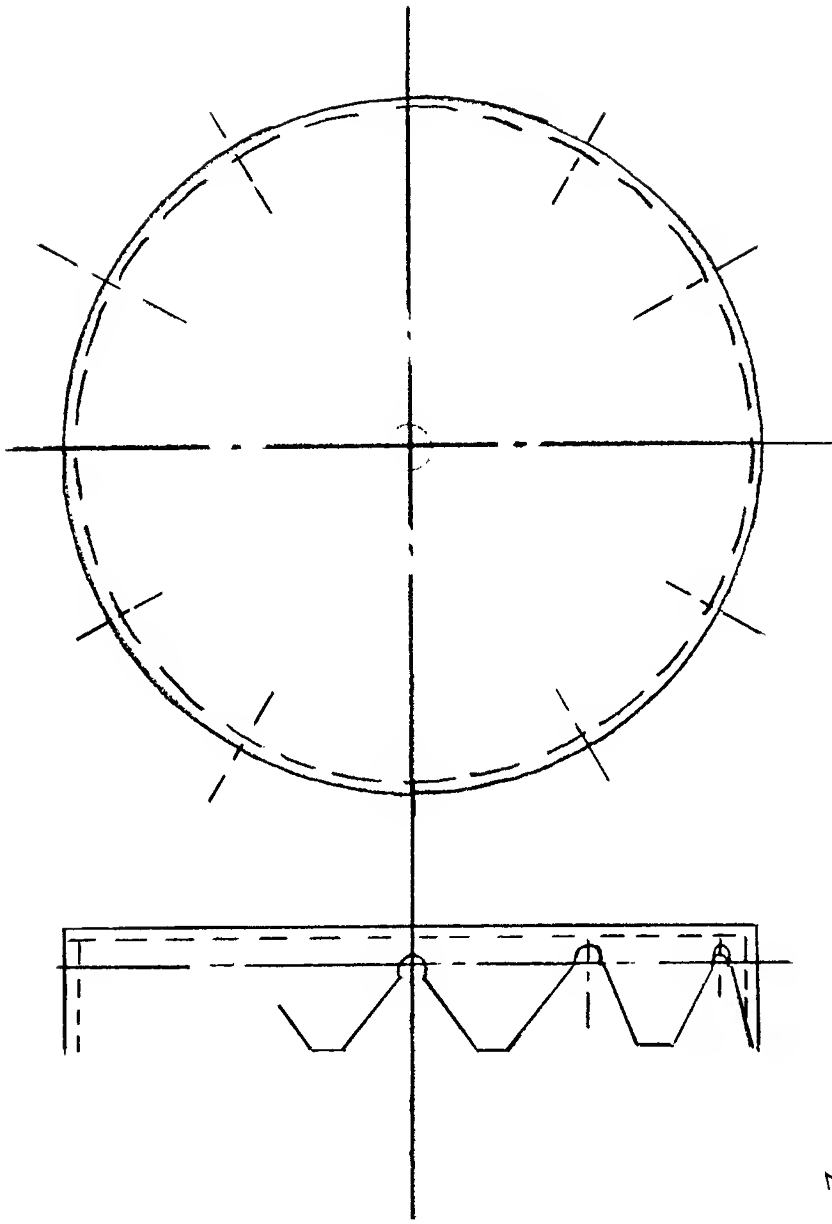

CURVE III
CHIMNEY CAP COMPARISON
1. 2 1/4 DIA WICK - CAP ON
2. " " " - CAP OFF
3. 2 5/8 " " - CAP ON
4. " " " - CAP OFF
1. 3440 BTU/hr
2. 4200 BTU/hr
4. 6300 BTU/hr
3. 6300 BTU/hr
TIME MINUTES
GROSS WEIGHT LBS
0
10
20
30
40
50
.8
.7
.6
.5
.4
.3
.2
.1


NOTE:
CAP ON & BAFFLE IN
2 5/8" GLASS FIBER WICK
4 SECTIONS
CURVE V
FUEL CONSUMPTION
GBH MARK UP
2 5/8" DIA WICK
SNUFFER 1/8 ABOVE SCREEN (1" ABOVE WICK)
(6300 BTU/HR)
SNUFFER 1/8 SCREEN (3/4 ABOVE WICK)
(6100 BTU/HR)
SNUFFER EVEN WITH TOP OF SCREEN (1/4" ABOVE WICK)
(6900 BTU/HR)
0
10
20
30
40
50
TIME MINUTES
7.6
.5
7.0
.5
.4
.3
6.20
GROSS WEIGHT LBS



MODIFICATIONS TO
X1M1038 SNUFFER

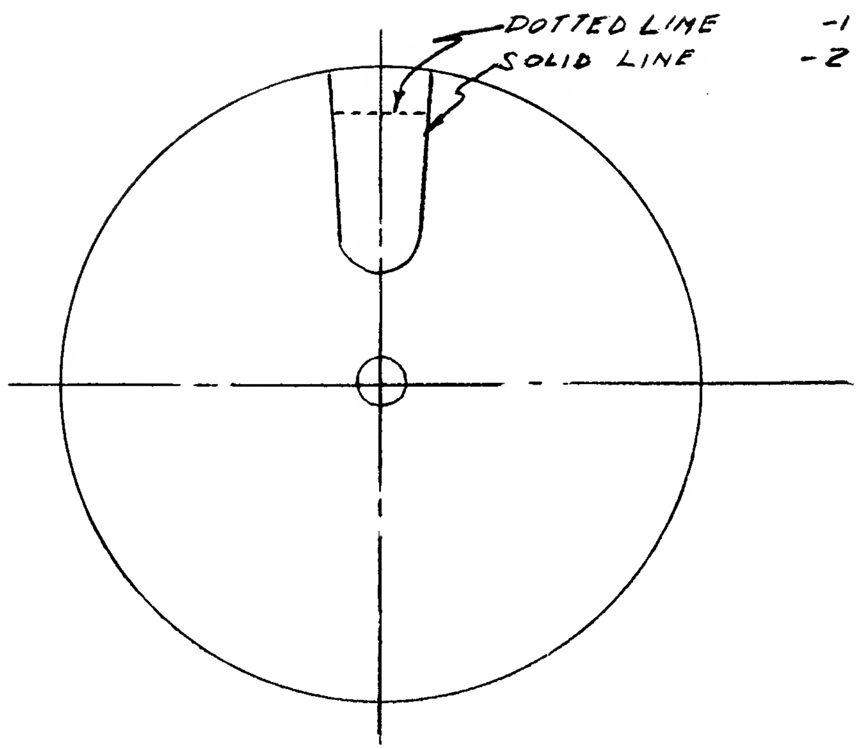
Figure 1



MAT'L .060 MILD STEEL

SAW TOOTH SNUFFER
EA2 HEATER

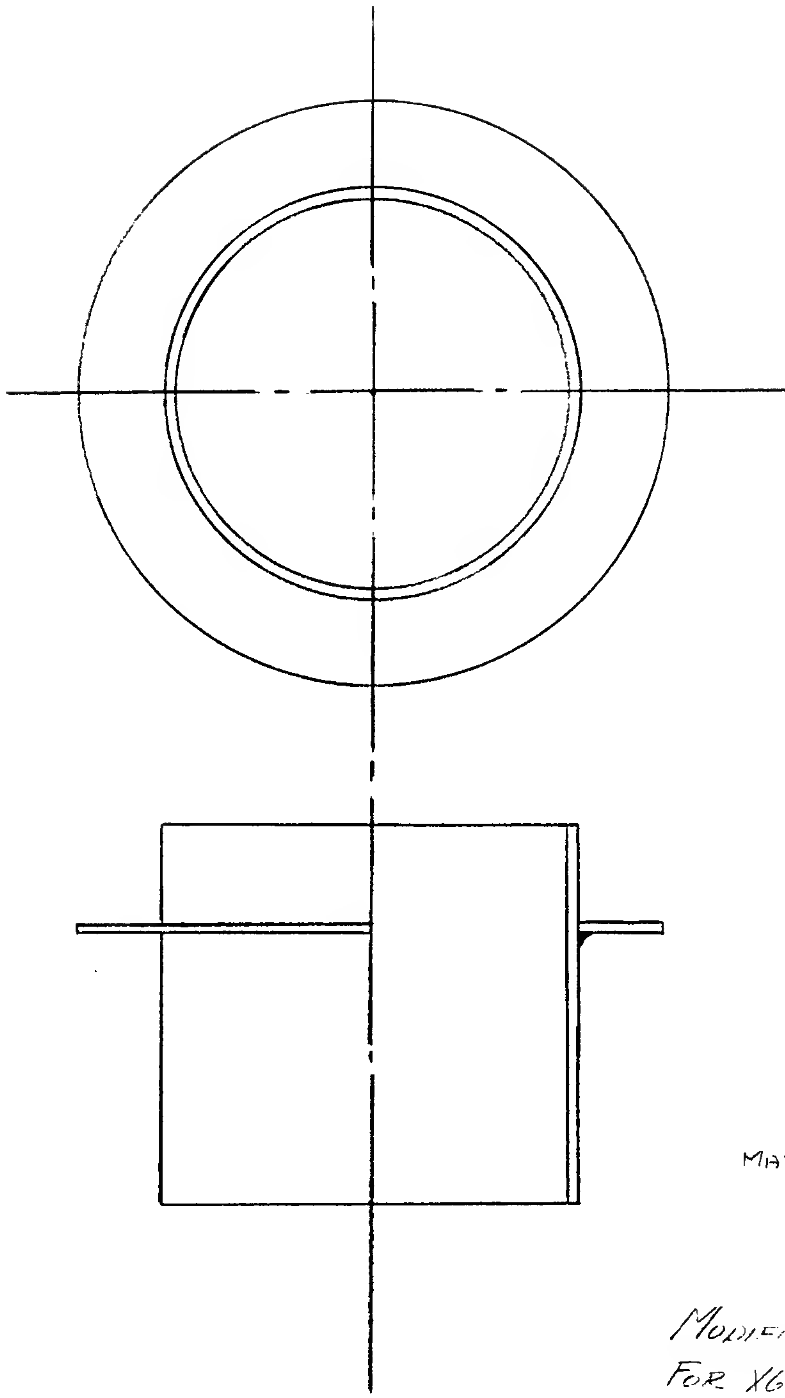
Figure 2



MATL .060 MILD STEEL

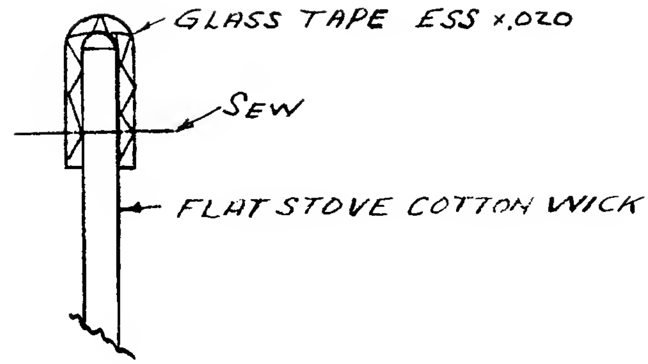
SPECIAL SNUFFER
FOR EHC HEATER

Figure 3

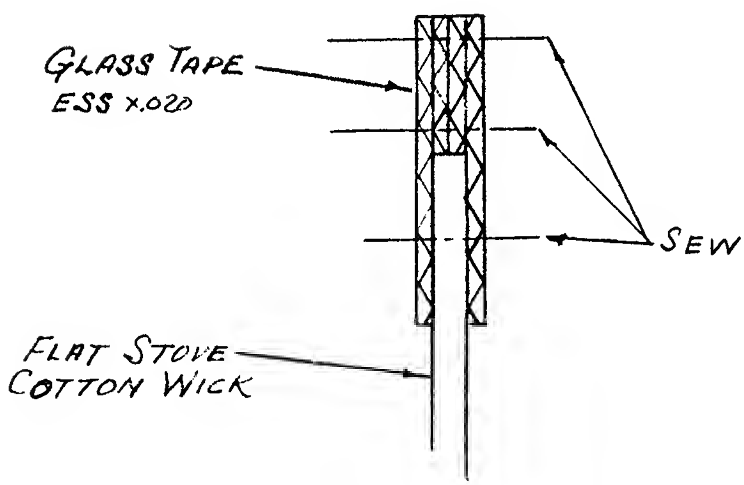


MODIFICATION SLEEVE
FOR X6M1003 HEATER

Figure 4

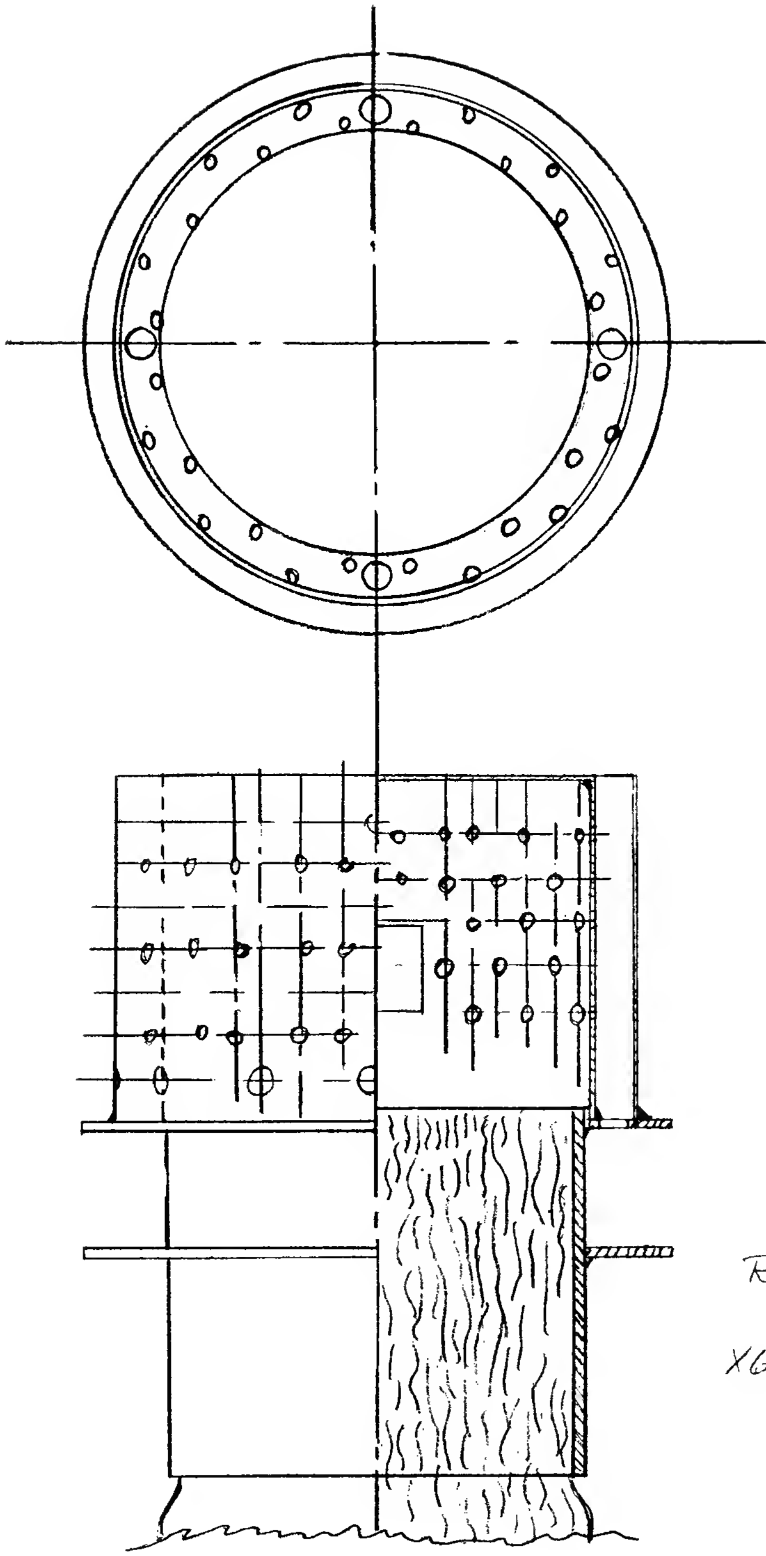


Wick Type 1
(Glass Capped)



Wick Type 2
(Glass Topped)

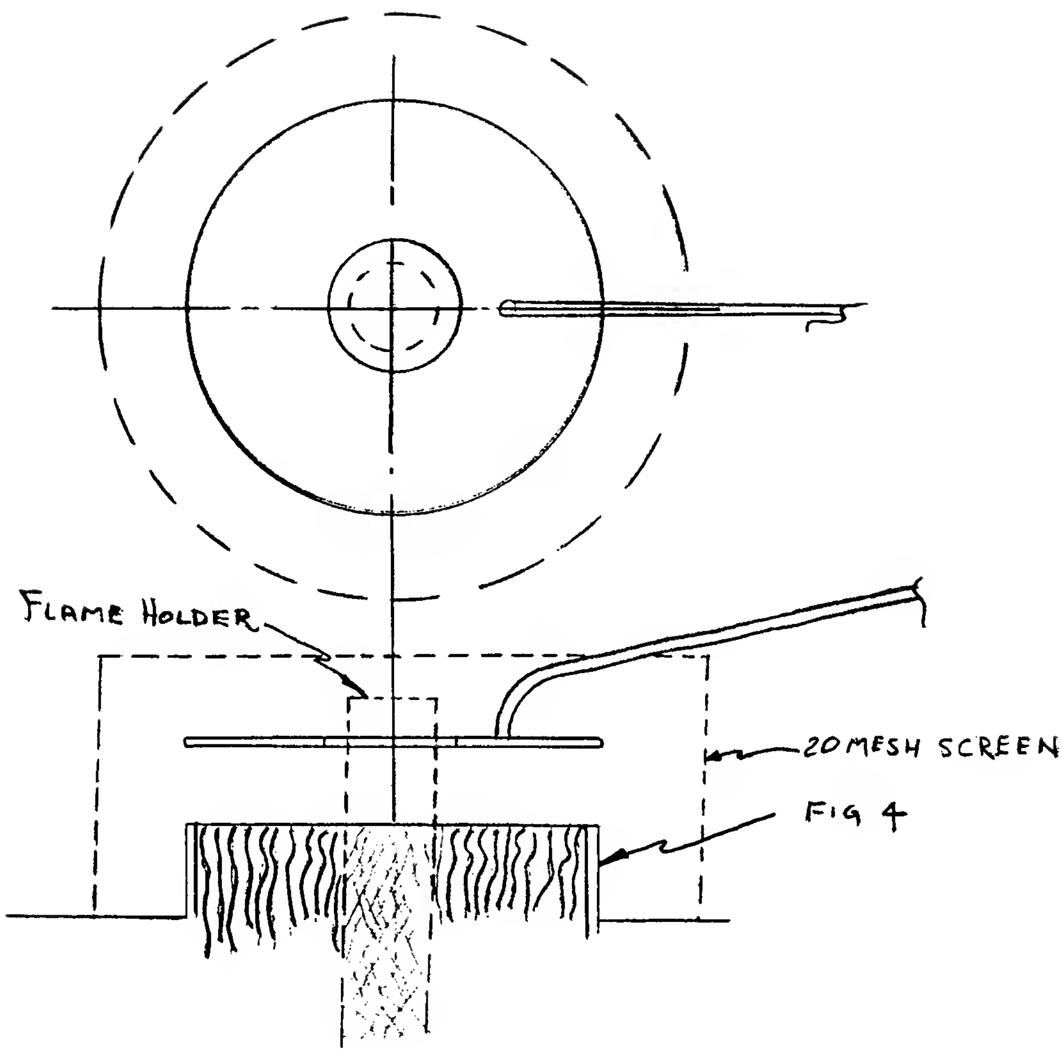
Glass-Cotton Wick
Combinations
Figure 5



MHTL .030 MILD STEEL

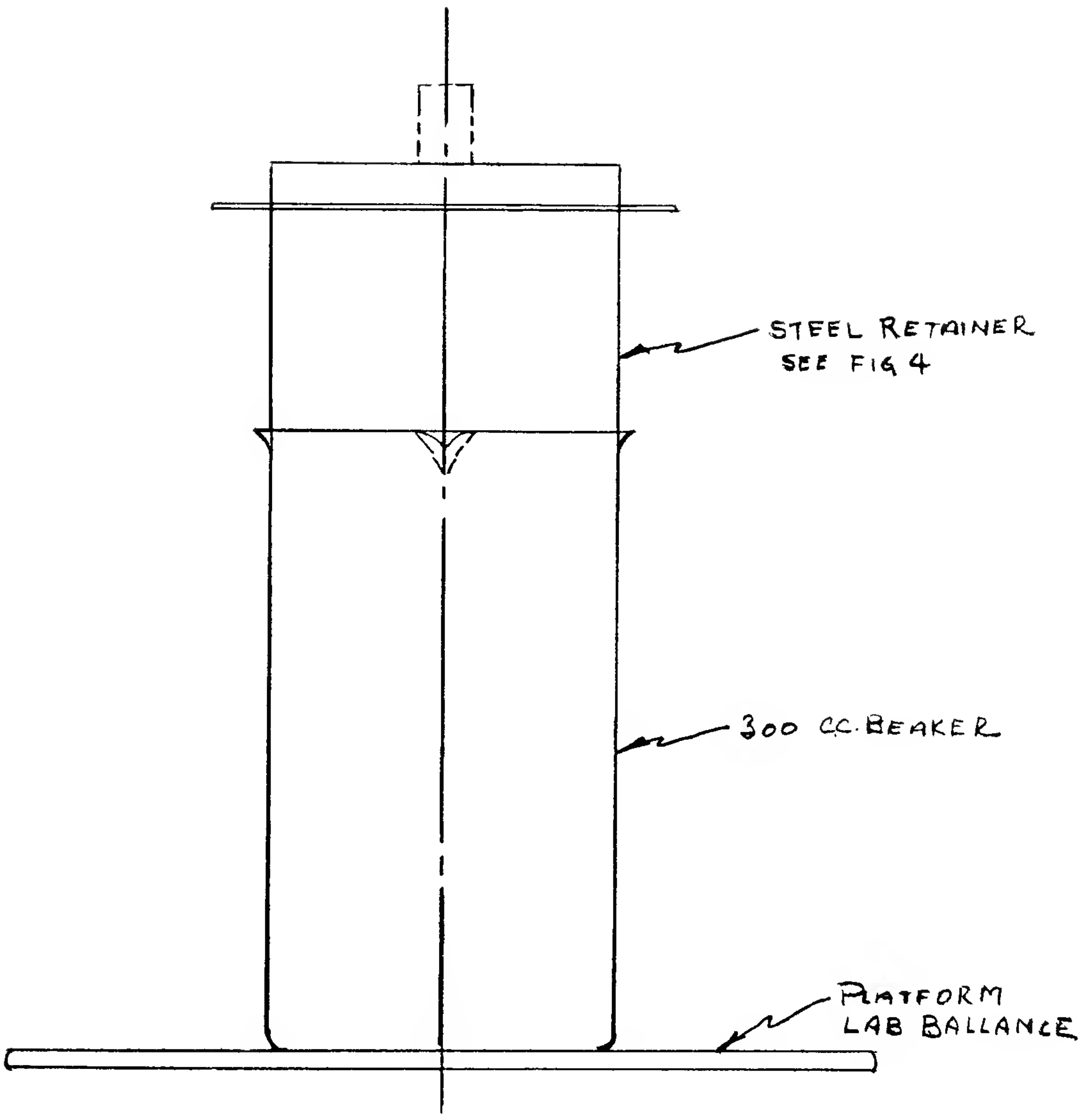
REPLICA SEARS BURNER
FOR
X6M1003 HEATER

Figure 6



FLAME HOLDER FOR X6M1003 HEATER

Figure 7



TEST SETUP
LABORATORY WICK
TESTS

Figure 8

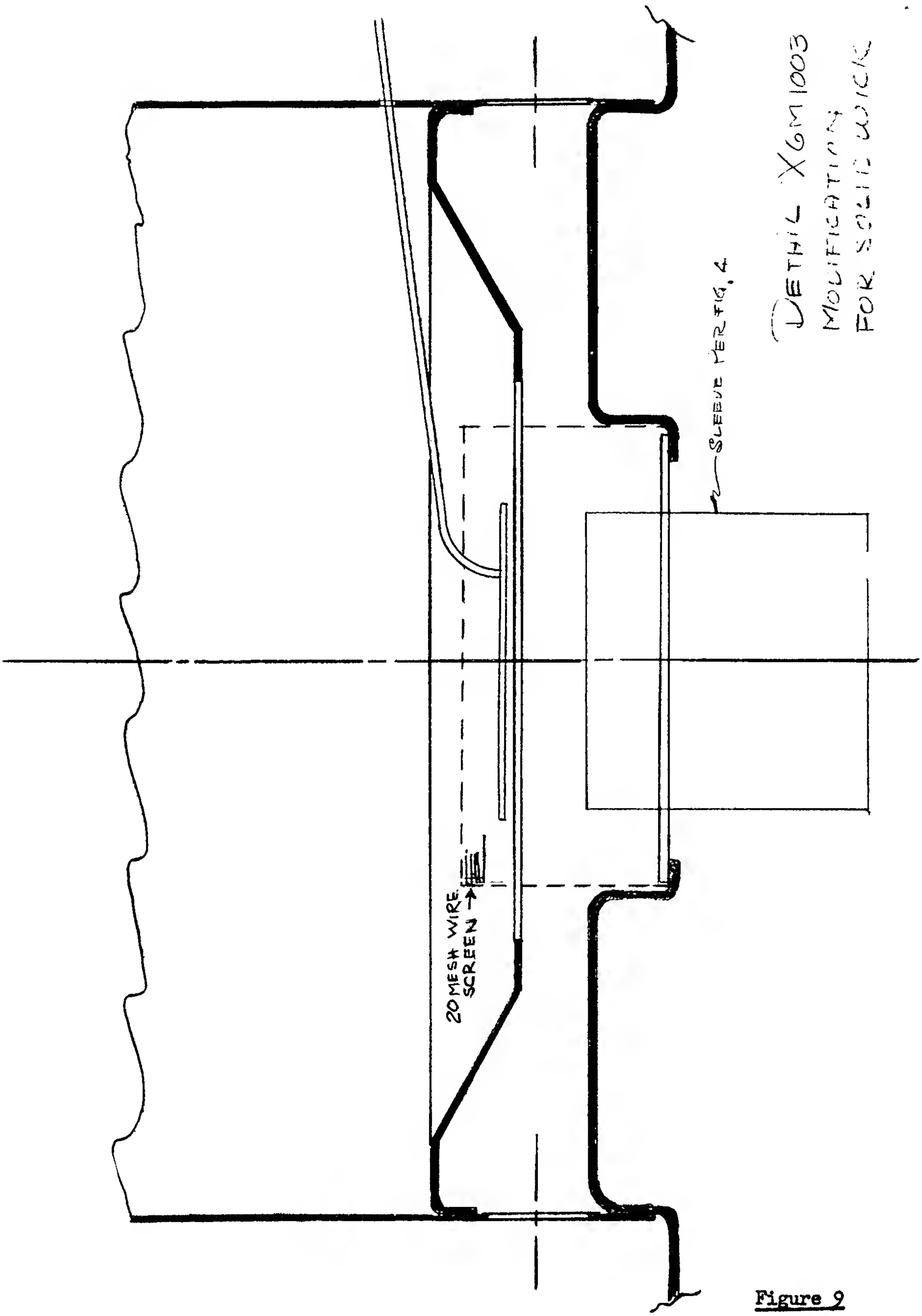

DETAIL X6M1003
MODIFICATION
FOR SOLID WICK
SLEEVE PER FIG. 4
20 MESH WIRE SCREEN

Figure 9

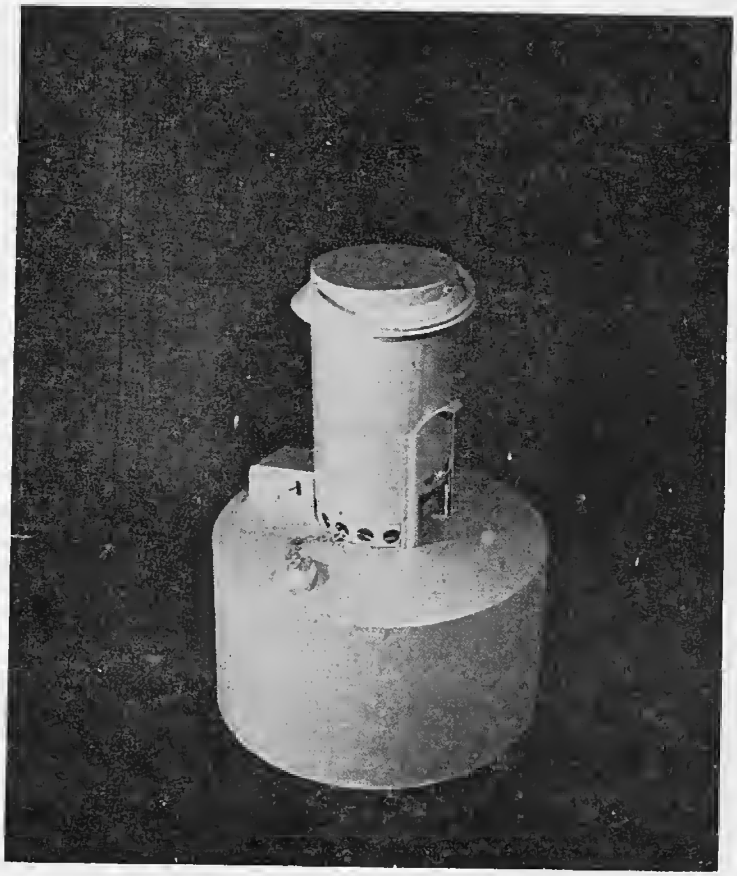


Figure 10. GB1 Mockup Assembled.

Figure 11. GB1 Mockup Disassembled.

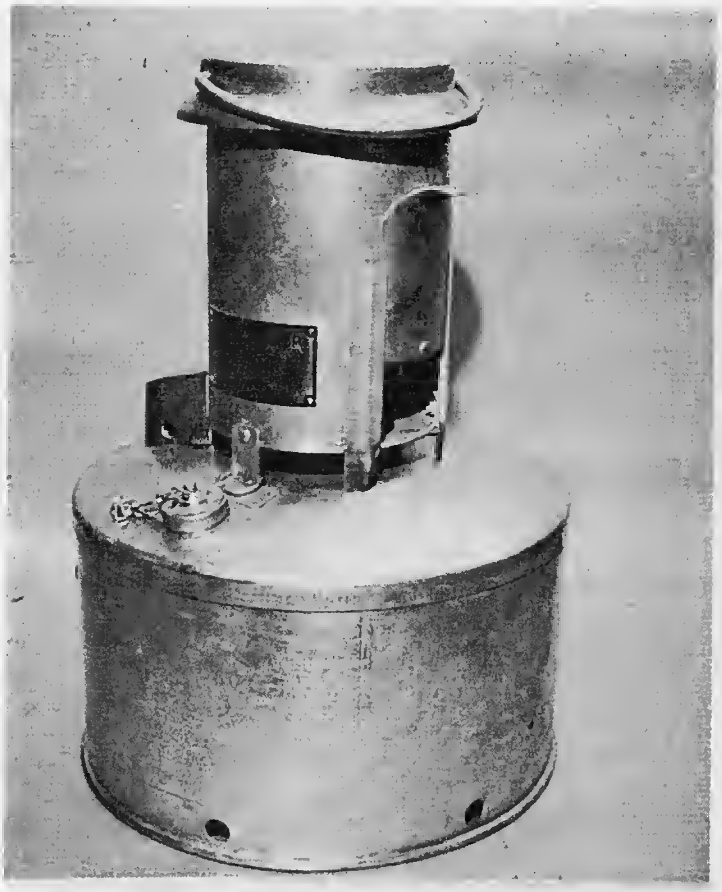


Figure 12 Model GB1 Heater.

Figure 13 Model GB1 Heater partially disassembled.

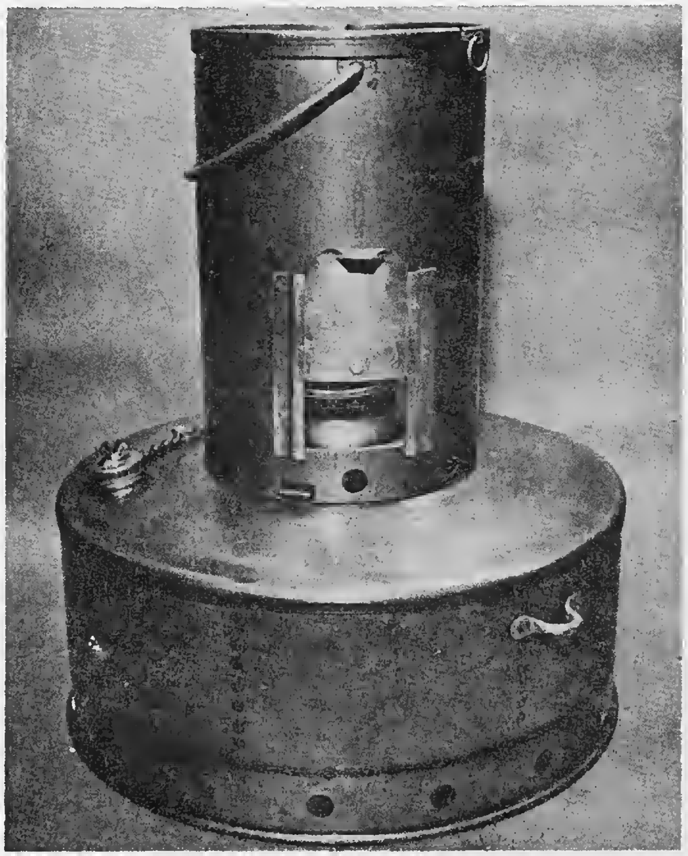


Figure 14 Model EA2 Heater.

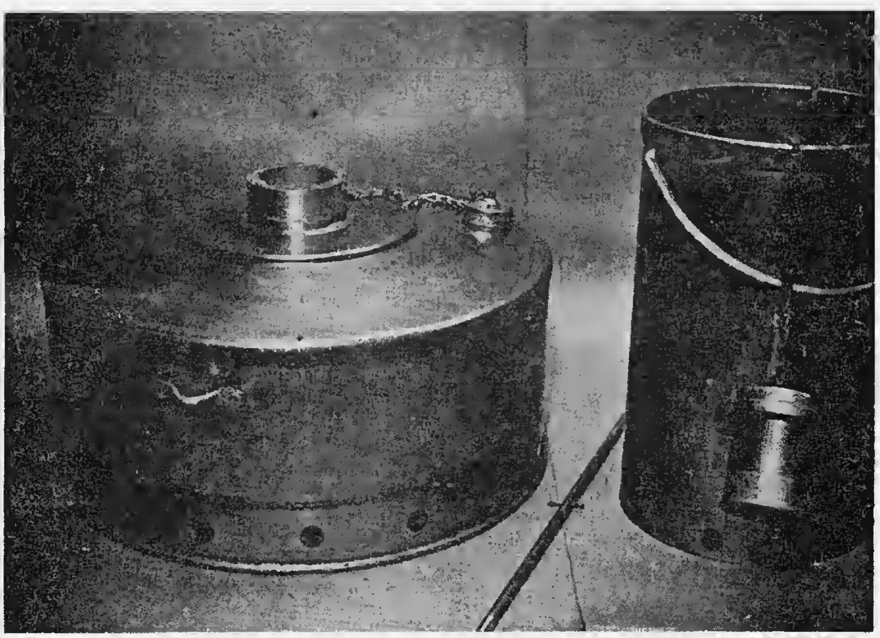


Figure 15 Model EA2 Heater partially disassembled.

Figure 16 Preco Experimental Heater.

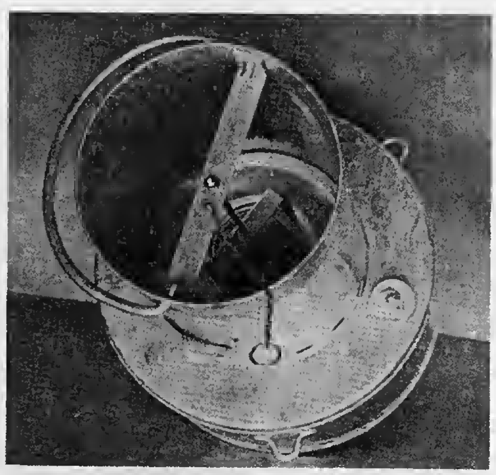


Figure 17 Preco Experimental Heater before modification - top view.

Figure 18 Sears Automobile Heater.

Figure 19 Sears Automobile Heater partially disassembled.

Figure 20 Sears Automobile Heater wick assembly.

APPENDIX F

PRECO REPORT RG10:
MODEL GB1 HEATER CONTROL MECHANISM

Report No. RG10

MODEL GB1 HEATER CONTROL MECHANISM
(Experimental Model)

November 8, 1948

Written By D Mannaf Fuller
Approved H C Fuchs
Approved R K Boemer

Typed:mr

OBJECT

Record the history of the design of the Model GB1 Heater (Experimental) Thermostat in 1946-1947.

CONCLUSION

1. A thermostat using a compensated vapor filled bellows was designed (Drawing X5G102).

2. The thermostat functioned satisfactorily but was unduly influenced by the temperature of the fuel in the heater.

3. The unit was much too complicated and fussy to adjust for economical manufacture in quantity.

4. The dial should be more accessible and the seal provision is not necessary.

RECOMMENDATIONS

Further work on thermostats should concentrate on units with a more positive motion and force. Of the commercially available units a bimetal strip or a liquid filled bellows will probably be the most desirable. Bimetal will produce a long stroke with small force, and liquid filled bellows will produce a short stroke with very large force. Neither type will require altitude compensation.

Effort should be made to isolate the sensitive element from temperature influence by the fuel.

PROCEDURE & DISCUSSION

Late in September, 1946, after the burner configuration seemed to be satisfactory, the design of the thermostat was started.

A brief preliminary consideration was made of the various types of temperature responsive elements. It was guessed that a vapor filled bellows unit would be best suited to our application, since we thought it produced long travel with large force and needed no over travel provisions.

From this premise the following specification was drawn for the thermostat:

1. Temperature range of exposure, -40 to +140°F.
2. Operating temperature range, +30°F. to +60°F.
3. Operating differential for stroke of $\frac{1}{4}$ to $\frac{1}{2}$", 6°F.
4. Maximum operating load, 10 lbs.
5. Life Cycles, 100,000.
6. Maximum diameter, 2".
7. Maximum change in calibration for 10,000 ft. altitude change, 3°F.

This specification was sent to all known manufacturers of bellows with the request that parts be delivered in November, 1946, All but the Bridgeport Thermostat Company replied that delivery was impossible. The unit Bridgeport Thermostat Company proposed was currently being manufactured by them for a steam regulator. It was a 2"dia. isobutane charged bellows which built up a force of about .7# per °F. temperature change and had a total force of 34# at 30°F. The spring in the unit allowed about a .005 inch stroke per °F. Because time was getting short we ordered the bellows assembly without the container and spring, and planned to design our own mechanism.

In the meantime, from the tests on the Model GB1 mockup, it appeared that if the snuffer plate was bounced up and down rapidly, in a manner which we thought simulated the vibrations in a train, the pilot would often be extinguished. To prevent bouncing we cosidered either counterbalancing the snuffer arm or using a toggle to give it a snap action. Layouts and discussion indicated that space limitations would not permit counterbalancing and that the snap action would probably be more positive. Therefore, we proceeded to design the thermostat around the Bridgeport bellows and the snap action on the snuffer.

The first problem was that of altitude compensation. This was necessary because the fill material, isobutane, has a vapor pressure at 30°F. of only 8 PSI, and at 60°F., 24 PSI. Therefore, the atmospheric pressure change of 4.6 PSI from sea level to 10,000 feet would cause a change in calibration of 6° to 18°F. The amount of variation is dependent on the thermostat dial

setting which regulates the vapor pressure necessary to start movement of the mechanism. A fill with a higher vapor pressure could not be permitted because at 140°F., the highest temperature of exposure specified, isobutane has a vapor pressure of 110 PSI which is very close to the maximum pressure the bellows will withstand.

Compensation, however, was relatively easy, being accomplished by placing a bellows of the same size and construction, but filled with air, in opposition to the vapor filled bellows. The air, when compared to isobutane vapor over the temperature range in which the thermostat was to operate (30° - 60°F.), is virtually non-responsive to temperature change. Thus, no sensitivity was sacrificed except that caused by the spring rate of the bellows and the air when it was compressed by movement of the power bellows.

The problem of providing adjustment for response to different temperatures was principally one of arrangement of parts in the allowable space. Adjustment of a vapor filled unit is accomplished by varying the force urging the bellows against a stop. As is common practice, this force was provided by a spring which could be compressed or relaxed by turning a calibrated screw. When the temperature of the vapor inside the bellows was such that the total force exerted by the vapor pressure equalled the spring load, movement of the mechanism started. However, even though every effort was made to hold spring rates to a minimum, the adjusting spring, bellows, and air in the compensating bellows had a spring rate of 200 lbs. per inch. Thus, an additional temperature change of 22°F. was required for continued movement of the mechanism through the 3/16" stroke required.

To reduce this temperature change requirement, a set of 3 springs was arranged at the bottom of the thermostat unit in such a manner that they introduced a negative spring rate of 200 lbs. per inch, making the unit rateless. Theoretically, if the rates exactly cancelled, the unit would move through the complete stroke when the force of the vapor pressure overbalanced the spring load because the bellows would exert a constant force through the stroke. This is from the fact that in a closed space filled by a vapor and its liquid, the vapor pressure at a given temperature is independent of the volume.

There was no time to mock up a complete thermostat to check its operation, but the negative spring rate arrangement, bellows, and adjusting spring were individually checked to prove our calculations. It was unfortunate that a complete mockup was not

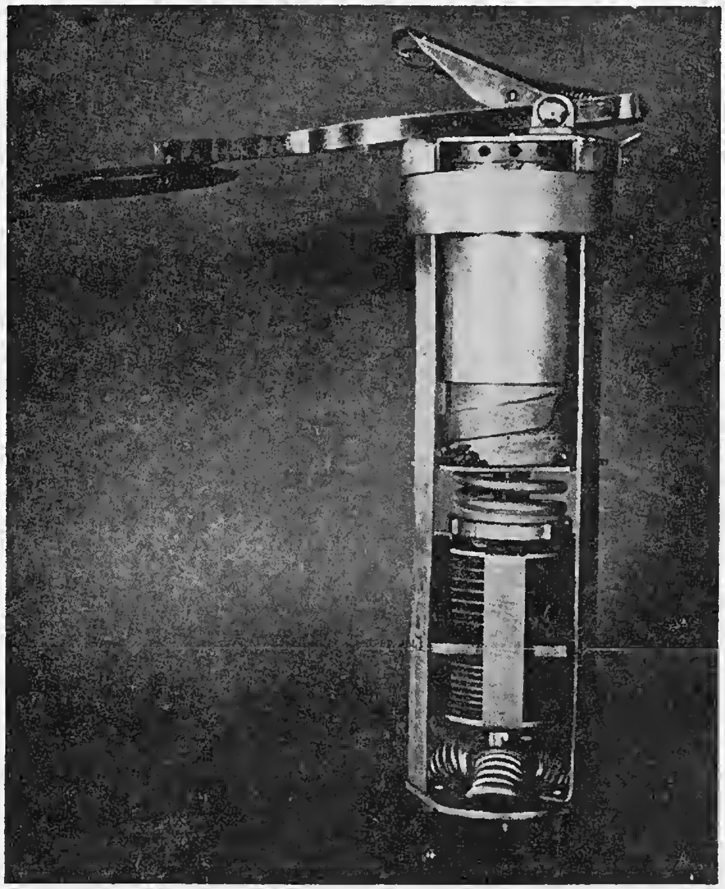
made because the mechanism developed enough friction from the high loads in the springs, and it was so difficult to make the rates exactly cancel, that it was necessary to hand work each thermostat to make it operate. This condition of high friction and unavoidable spring rate increased the operating differential to 11° or 13°F. from the 3° or 4°F. which we had expected. Also contributing to this condition was the sluggishness of the power bellows. It seems that the sudden expansion of the bellows caused a slight reduction in the temperature of the vapor, and thus the force exerted. Operation for these reasons was jerky and uncertain.

These units were installed in heaters and given a preliminary testing in a cold room. It was found that the fuel temperature was the largest influencing factor on the temperature of the bellows. This fact was both good and bad. Bad, in that it took 8 to 10 hours for the fuel and bellows to cool from 60°F. to 30°F. when placed in a 25°F. room. Good, in that the effective operating differential was reduced to about 5°F. because the fuel warmed and raised the temperature of the bellows about 8°F. above the surrounding air when the heater turned on to full flame.

These units were included in the AAR-USDA tests of the winter of 1946-47. They gave a satisfactory performance record, but it was necessary to be sure that the fuel temperature at the initial and subsequent refuelings was near 32°F., the temperature for which the thermostat dial was set. Details of the thermostat performance on these tests can be found in the AAR & USDA comprehensive reports for tests #14 and #15.

From the experience gained in assisting with these tests, it was learned, contrary to our previous beliefs, that the thermostat adjusting dial should be easily accessible and that a tamperproof seal on the adjustment was not necessary.

Snuffer



Snap Action Toggle

Adjusting Nut

Adjusting Screw

Adjusting Spring

Power Bellows

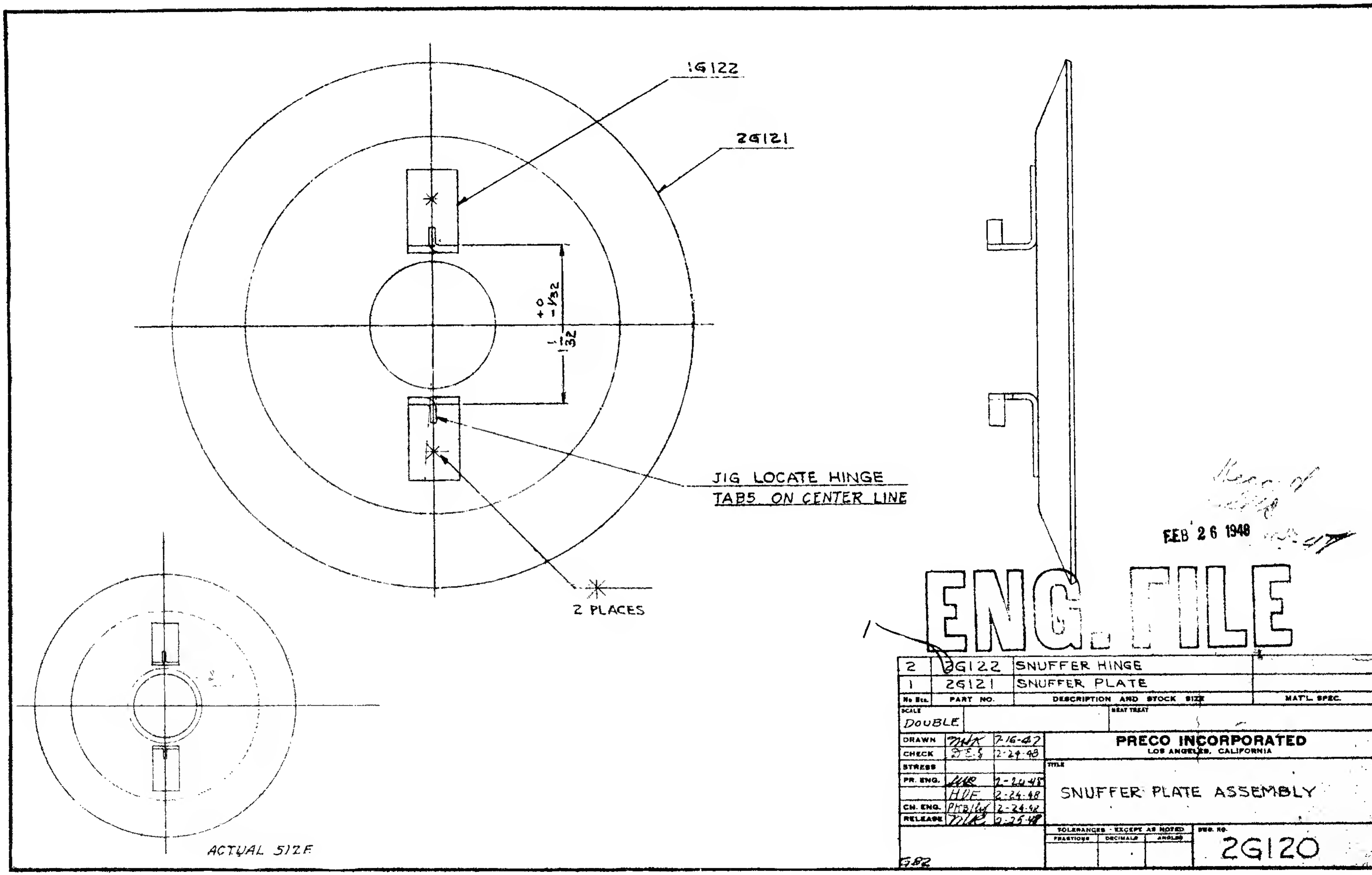
Altitude Comp. Bellows

Negative Rate Spring
Arrangement

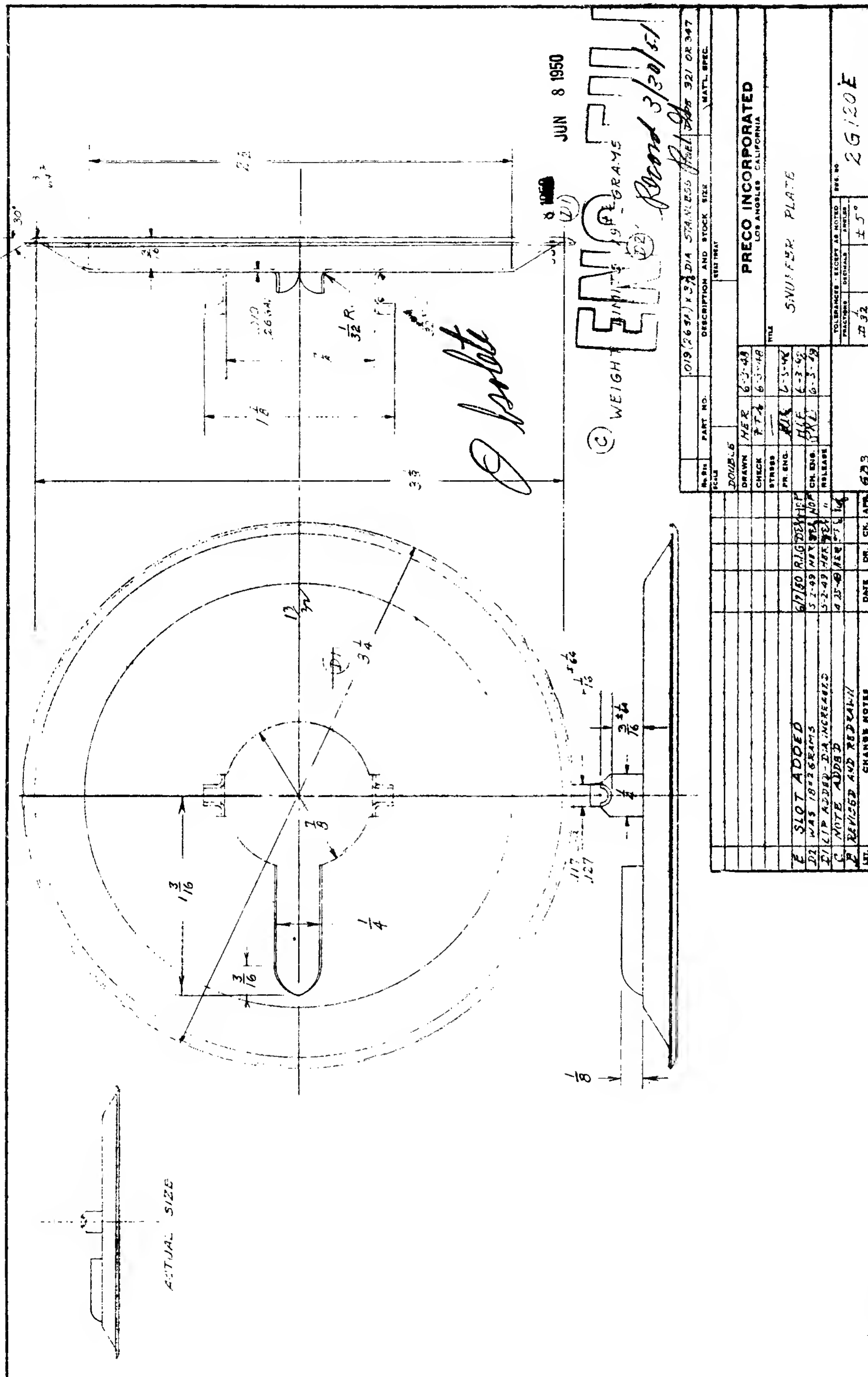
Model GB1 Thermostat Assembly

APPENDIX G

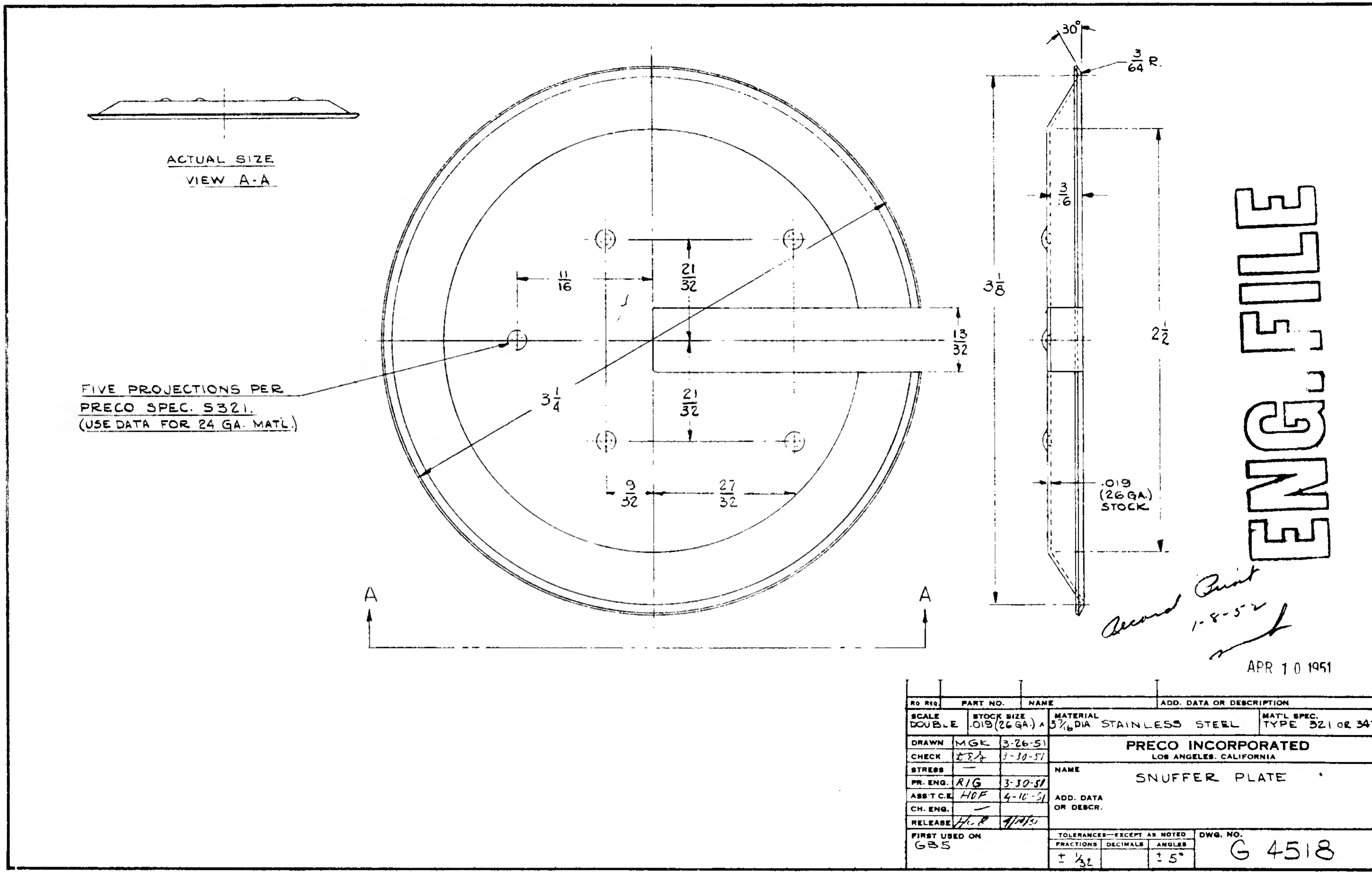
SNUFFER PLATE DRAWINGS



REPRODUCTION REDUCED IN
SIZE FROM ORIGINAL

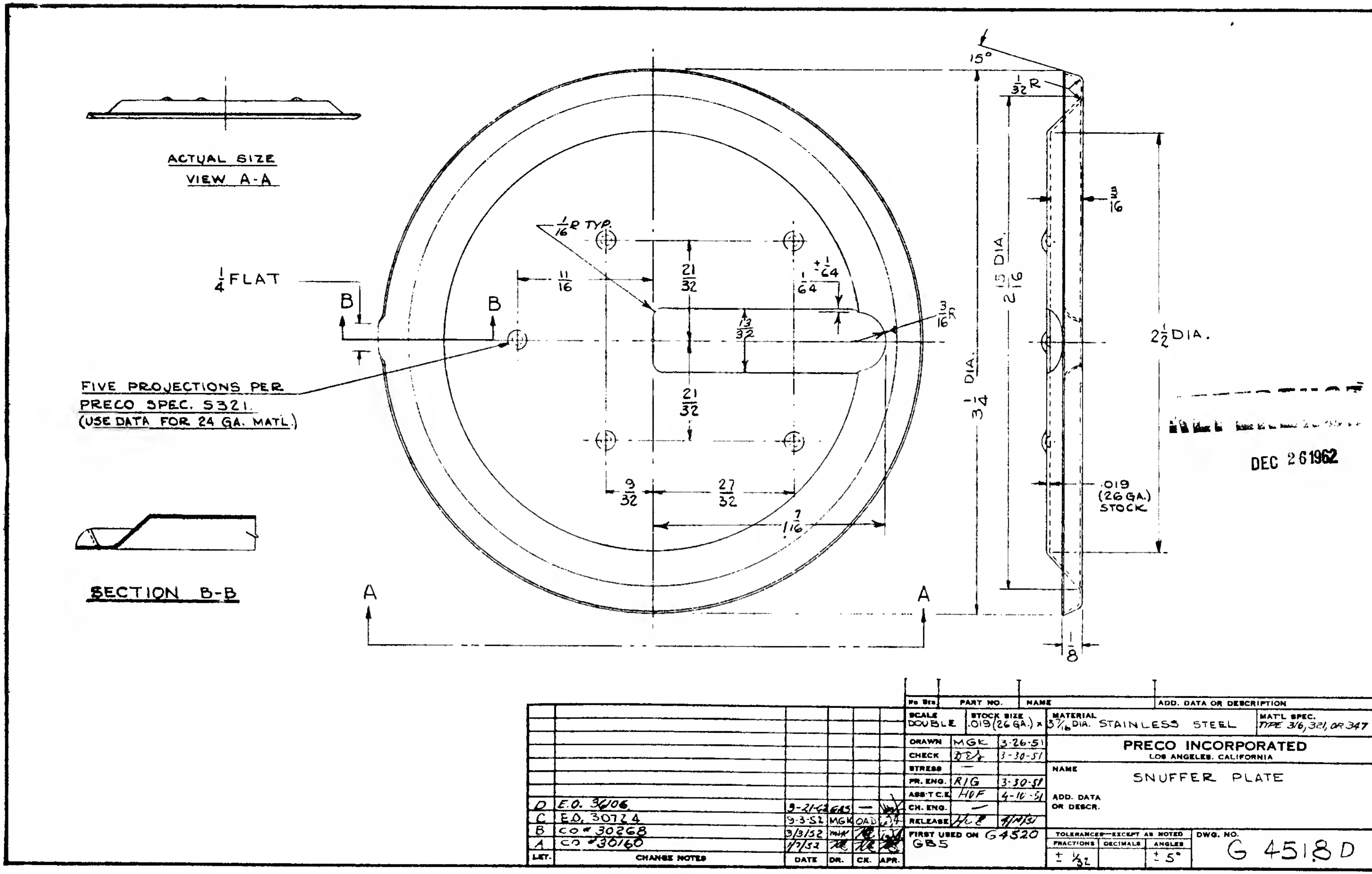

PRECO INCORPORATED
LOS ANGELES CALIFORNIA
SNUFFER PLATE
2G120E
JUN 8 1950
ACTUAL SIZE
SLOT ADDED
REVISED AND REDRAWN
CHANGE NOTES
DOUBLE

PR



PRINTED ON CLEARPRINT NO. 1000H FORM 152

REPRODUCTION REDUCED IN
SIZE FROM ORIGINAL



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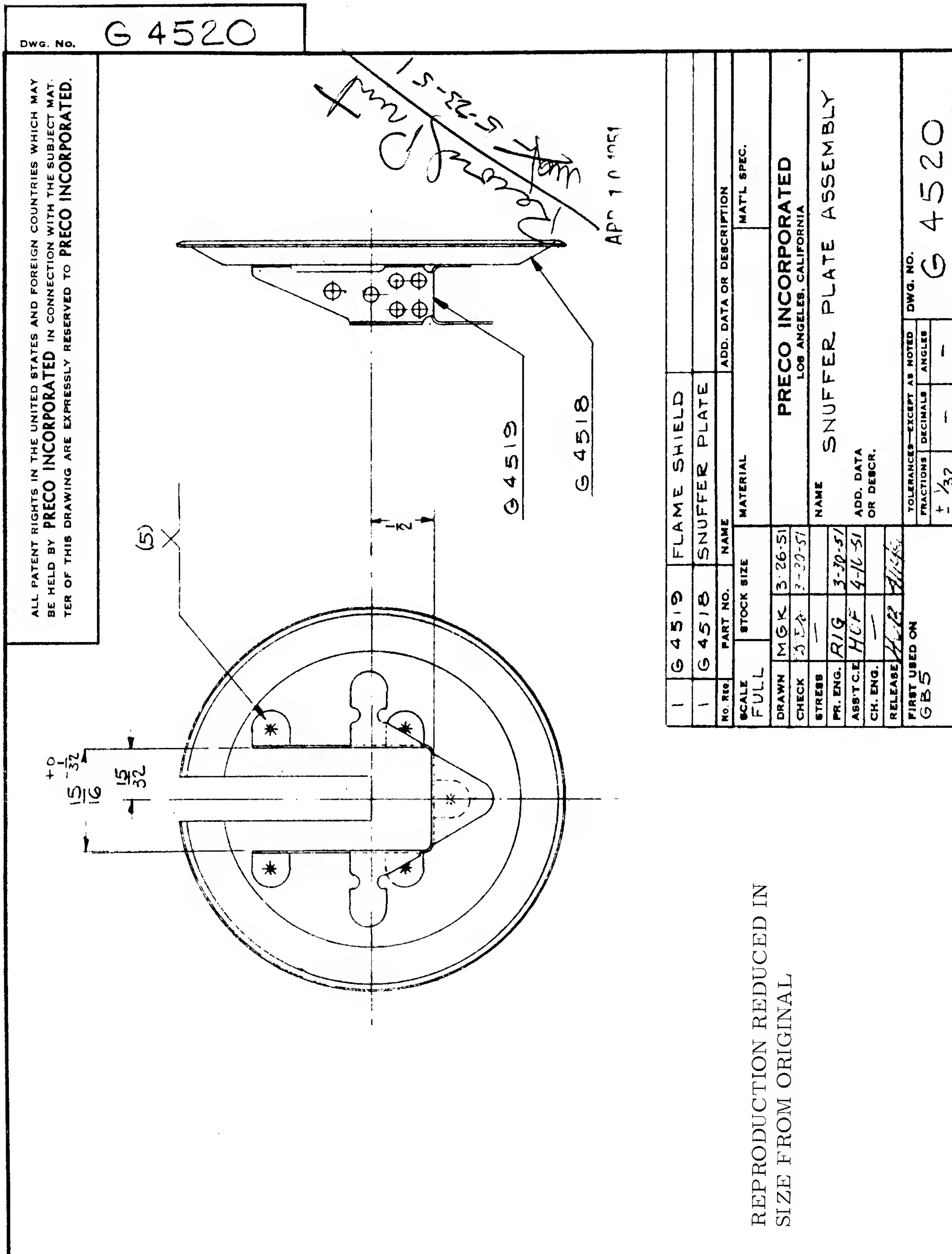
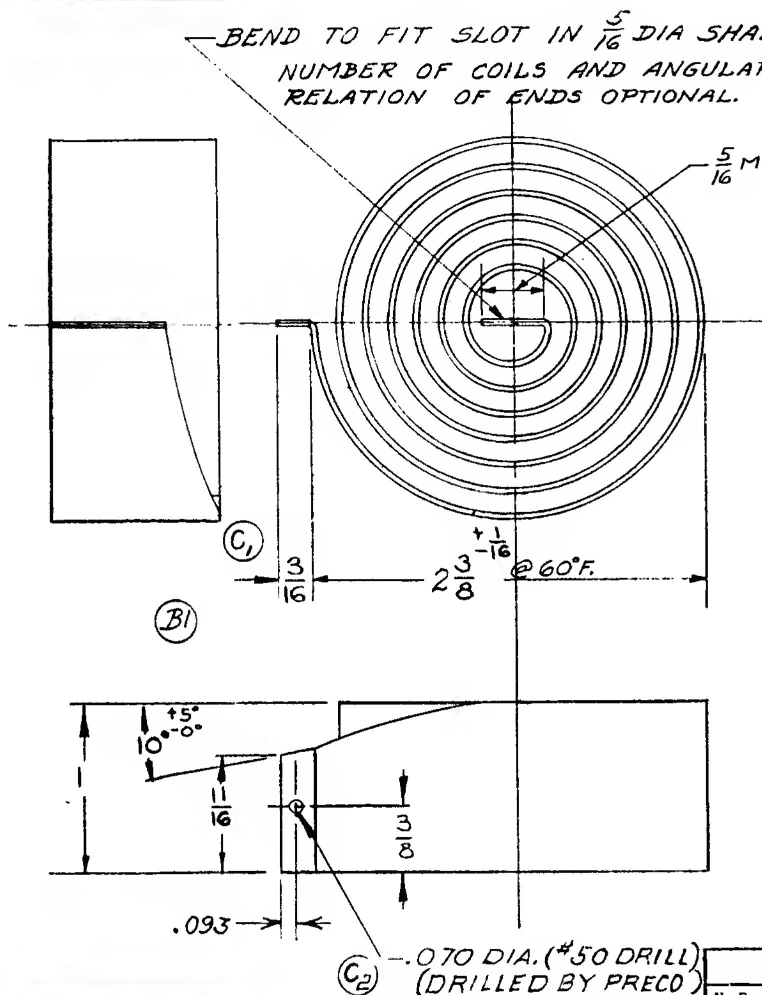
SIZE FROM ORIGINAL



REPRODUCTION REDUCED IN SIZE FROM ORIGINAL

APPENDIX H

THERMOSTAT COIL DRAWING



SPECIFICATIONS

1. 1.06 / 1.24 DEGREES ANGULAR ROTATION PER DEGREE F.
2. .85 INCH OUNCE MINIMUM TORQUE PER DEGREE OF ROTATION.
3. ROTATION AND TORQUE SPECIFICATIONS ARE APPLICABLE BETWEEN 32°F AND 65°F WHEN COIL IS MOUNTED IN 2G113 TUBE OF G3025 THERMOSTAT ASSEMBLY.
4. MATERIAL - CHACE Nº 6650 OR EQUIVALENT.
5. HIGH EXPANSIVE SIDE INSIDE.
6. COIL MUST NOT TAKE A PERMANENT SET BETWEEN -40°F AND +130°F. IF ENDS ARE RIGIDLY HELD AT THE FREE POSITION: CORRESPONDING TO +30°F. AND +60°F.
7. NO BINDING BETWEEN TURNS ALLOWED WHEN COIL IS MOUNTED IN 2G 113 TUBE OF G 3025 THERMOSTAT ASSEMBLY.

LET.	CHANGE NOTES	DATE	DR.	CK.	APR.
F	E.O. 33012	2-20-57	W.H.	—	JRL
E	E 31470	6-10-54	JNB	JFF	[illegible]
D	E.O. 31242	1-14-54	GMM	[illegible]	[illegible]
C3	±.010 DEC. TOL. ADDED	4-18-50	R.G.	DES	HOF
C2	.070 HOLE ADDED	"	"	"	"
C1	7/32 was 3/16	"	"	"	
B1	WAS 7/16 × 60° B2 TOL. REMOVED	4-8-48	HER	DES	HOF
A	REVISED & REDRAWN				

No Req.	PART NO.	DESCRIPTION AND STOCK SIZE	MAT'L. SPEC.
		SEE SPEC. 4 ABOVE	

SCALE: FULL
HEAT TREAT:

DRAWN	HER	3-12-48
CHECK	DES	3-12-48
STRESS	—	
PR. ENG.	[illegible]	3-12-48
CH. DES.	[illegible]	3-12-48
CH. ENG.	[illegible]	3-12-48
RELEASE	[illegible]	[illegible]

GB3

PRECO INCORPORATED
LOS ANGELES. CALIFORNIA

TITLE: BIMETAL COIL

TOLERANCES · EXCEPT AS NOTED

FRACTIONS	DECIMALS	ANGLES
± 1/32	±.010 (C3)	(B2)

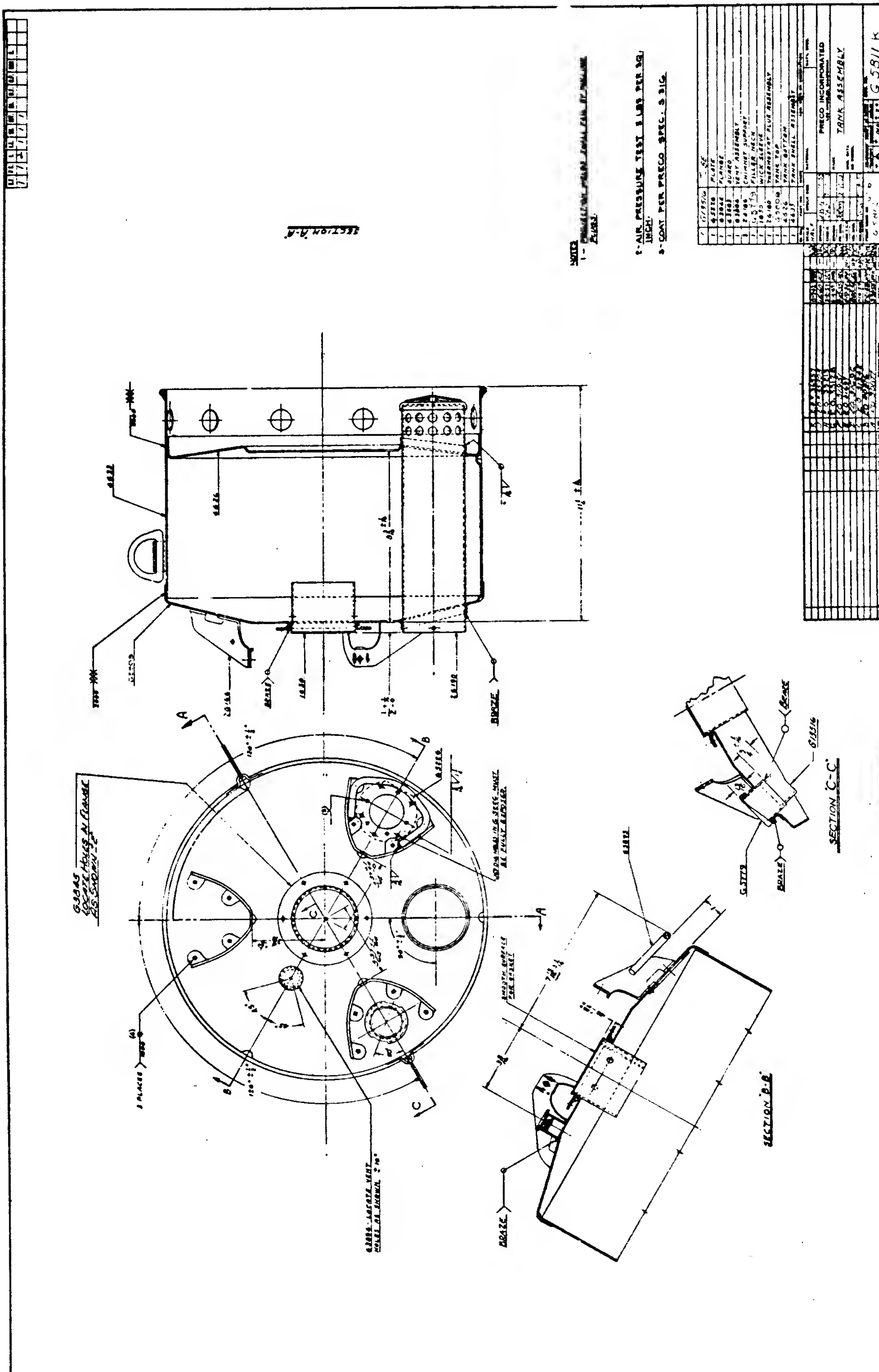
DWG. NO. 1G110F

195-M "ALBANENE"—K. & E. CO., N. Y.—REG. U.S. PAT. OFF.

REPRODUCTION REDUCED IN
SIZE FROM ORIGINAL

APPENDIX I

TANK ASSEMBLY DRAWING



REPRODUCTION REDUCED IN SIZE FROM ORIGINAL